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Review

Extreme climatic events and host–pathogen interactions: The impact of the 1976 drought in the UK

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ABSTRACT

Intense, long droughts have increased in occurrence since the 1970s and have been linked with global climate change. Extreme climate alters the risk of pathogen infections and diseases in both animals and plants, although little is known about the impact of any single event on host–pathogen dynamics in a wide range of species. Evaluating past climatic events can provide valuable information on complex interactions that occur between hosts, pathogens, and the environment, thereby paving the way for predictive models and ultimately early and efficient response to disease threats. The present study reviews the substantial impact of the 1976 UK drought on climate-driven host–pathogen associations. This 16-month drought had a devastating effect on flora and fauna and is considered a benchmark for dry conditions in this country. Changes to the occurrence of infections in farmed and wild animals and plants are presented in terrestrial, freshwater, and marine ecosystems and the implications for pathogen transmission under extreme climate conditions are assessed.

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1. Introduction

Global climate change as a result of human activities is a widely accepted phenomenon. Average atmospheric and surface temperatures along with sea levels have risen significantly over the last 50 years. A warmer global climate system consequently accelerates the hydrological cycle, increasing the likelihood of extreme

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weather events such as droughts, heat waves, storms, and heavy rainfall with associated flooding (IOM, 2008). In particular, intense long droughts can have a devastating impact on regional agriculture, water resources and the environment (Sheffield et al., 2012).

Within the UK, at temperate latitudes, climate change is predicted to result in an increase in average temperatures of 2–4 °C by the 2080s with an increased frequency of heatwaves in summer and more intense recurrent rainfall events. However, annual precipitation may be little changed but summer rainfall could fall by up to 50%, offset by an increase in winter rainfall, with a greater risk of floods and drought (Hulme et al., 2002). These predicted changes will be more marked in the south of the country with a greater impact on natural than in agricultural systems (Chancellor and Kubiriba, 2006).

An increased occurrence of extreme weather events may, in turn, alter the risk of infectious disease incidence in a wide range of pathogens of animals and plants. Climate can directly influence both the replication rates and dissemination of pathogens and the movement, replication and abundance of hosts. Ecosystems and human behaviour will also be indirectly affected, thus leading to changes in the incidence, seasonal occurrence and geographical range of pathogens (IOM, 2008), although a number of additional differences in the degree of infectious disease risk separate farmed and wild organisms.

An important component of forecasting pathogen outbreaks in a changing climate can be derived from historical analysis which provides a valuable, wide-ranging, perspective on climate and infectious disease and contributes to our understanding of complex interactions between biological and physical environments. This paves the way for the development of predictive models and, thereby, for early and efficient responses to infectious disease threats (IOM, 2008).

The impact of extreme climatic events on a small number of, specific, host–pathogen relationships has previously been documented (Szidat, 1968; Kennedy, 1998; Overstreet, 2007) and drought, in particular, has long been known to have significant effects on the occurrence of parasitic diseases e.g. Szidat (1968).

Within the UK the potential effects of climate change have been assessed in a limited number of prominent infectious diseases of animals and plants (Baylis, 2006; Wilkinson, 2006; Chancellor and Kubiriba, 2006; Baylis and Githeko, 2006; Gale et al., 2009). These studies focus on pathogenic species that are of the greatest current importance to the UK (Baylis, 2006), including notifiable exotic diseases and non-notifiable endemic diseases resulting in the greatest economic losses. Although such prioritisation is concordant with an anthropocentric view of climate change it largely ignores the impact of pathogens on animals and plants that have no obvious medical, veterinary, or economic importance. Such an approach may be shortsighted as it leaves little room to consider the interconnected nature of organisms, their pathogens, and the way changes to species community structure that may be regarded as insignificant to social economics can cause a cascade of effects through ecosystems that can ultimately impact those animals and plants that are important to human welfare e.g. Marcogliese and Cone (1997).

A further weakness of studies focusing on only one or two species is the tendency to extrapolate results derived from this limited pool to other pathogens that share similar transmission strategies in order to create sentinels for making generalisations on the nature of the impact of particular biotic or abiotic factors (Kutz et al., 2005; Morand and Guegan, 2008). However, the response of a wide range of pathogens to any one factor or event has rarely been studied and therefore the validity of using a few 'keystone' species has not yet been proven. In the present study, by assessing the impact of one climatic event to the largest possible number of species infecting animals and plants from terrestrial, freshwater and marine ecosystems, we hope to determine trends that will prove useful in the study of pathogens within both farmed and wild organisms in a changing climate.

Drought is a recurring feature of the UK climate and can be defined on the basis of meteorological, hydrological or agricultural factors and its range and scale of impact can be determined according to its duration and spatial extent (Marsh et al., 2007). Ten major droughts have been identified since 1800 and all but one persisted for at least a year, often longer, and were associated with one or more notably dry winters (Marsh et al., 2007). The 1976 drought is considered a benchmark for dry conditions, particularly across much of England and Wales (Marsh et al., 2007) but also throughout northwest Europe where similar harsh conditions occurred (Stubbs, 1977). During this period the lowest flows of British rivers were recorded and there was a severe impact on surface water and groundwater resources (Marsh et al., 2007). In addition, this drought may be particularly useful for studies on climate change as it followed a 5-year cycle of mild winters throughout western Europe from 1971 to 1976 (Wright, 1975; Meteorological Office, 1976; Perry, 1978). In temperate latitudes mild winter conditions are predicted to become more frequent in the future under climate change (Hulme et al., 2002) and therefore an example of an extreme climatic event associated with these conditions is particularly valuable.

The 1976 drought in the UK attracted a great deal of scientific and media attention (Hearn and Gilbert, 1977; Cox, 1978; Hill and Avery, 1978; Pereira et al., 1978; Doornkamp and Gregory, 1980) and consequently there is far more literature devoted to this extreme climatic event than any other severe drought in the 20th century. Furthermore, the 1970s represented a high point of animal and plant pathogen surveillance in the UK, encompassing a wide range of pathogens, and resulting in an extensive collection of data for this period, making the 1976 event particularly valuable for understanding complex large-scale host–pathogen interactions under the influence of extreme climate.

From a meterological perspective the drought is defined as occurring over a 16-month period from May 1975 to the end of August 1976 and, with the exception of September 1975, each month had below average or average rainfall (Ratcliffe, 1978). The drought culminated in continuous very high temperatures throughout the summer of 1976, with extreme daily highs of over 30 °C occurring between 23rd June and 7th July, making it one of the warmest on record (Ratcliffe, 1976). At the end of August the weather broke and a period of heavy rainfall began which continued throughout the autumn (Ratcliffe, 1977a).

Based on the reported responses of a wide range of animals and plants, biologically the impact of the drought probably extended over a slightly different period likely beginning in the autumn of 1975 for some species, following that year's dry summer, and continuing through 1976 and into 1977 for other species. However, different organisms responded in different ways with many species experiencing only short-term effects, with a rapid recovery after the drought broke (Hearn and Gilbert, 1977; Jeffers, 1977). Nevertheless, some species suffered more protracted symptoms. For example, during 1976 many tree species showed premature browning and withering of foliage, yet by the late summer of 1977 only beech had begun to die in large numbers due to the previous year's drought stress (Jeffers, 1977; Doornkamp and Gregory, 1980). For the present review we consider a time scale from the summer (June–August) of 1976, when the drought reached its peak, to mid-1977 as the main period when the effects of host–pathogen interactions are most likely to occur.

The present study therefore assesses the impact of the 1976 drought on climate-driven host pathogen interactions in terrestrial, freshwater and marine systems, using as many examples as