WEATHER AND THE LONG-DISTANCE MOVEMENT OF RABBIT HAEMORRHAGIC DISEASE VIRUS

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ABSTRACT: Rabbit haemorrhagic disease virus (RHDV) escaped from a quarantined field trial in Australia in 1995 and spread through much of the Australian wild rabbit population within a year. On several occasions during this period RHDV established new foci of infection several hundred kilometres from previously reported outbreaks. These discontinuous range expansions were often associated with unusually heavy rainfall and/or with the movement of small low-pressure systems across the Australian continent. Vertical and horizontal air movement within low pressure systems could move vector-borne or aerosolised micro-organisms long distances, following which they might be returned to earth by downdrafts associated with heavy rain. This paper discusses two of these movements and the associated weather conditions. An understanding of long-distance movements of RHDV could contribute to our knowledge of the epidemiology of RHD, but it may also have wider implications, related to exotic disease control, to the determination of appropriate conditions for confining potential new candidate biocontrol agents under quarantine while they are being field tested prior to their possible release, and to the understanding of the epidemiology of any disease which is spread by wind-borne vectors or aerosol.

INTRODUCTION

Rabbit haemorrhagic disease virus (RHDV) escaped from a quarantined field trial on Wardang Island in Australia in 1995 and spread throughout much of the Australian wild rabbit population the following year (Kovaliski 1998). On several occasions RHDV established new foci of infection several hundred kilometres distant from previously reported outbreaks. Some of these discontinuous range expansions were associated with unusually heavy rainfall and/or with the movement of small low-pressure systems centred on the Australian mainland. Disease can be spread long distances by the wind (Pedgley 1983). The convection and advection of air within low pressure systems has the potential to move vector-borne or aerosolised micro-organisms long distances, following which they could be returned to earth by downdrafts generated by heavy rainfall or by the active flight of the vectors, thereby establishing new foci of disease some distance from previous outbreaks. This paper discusses some of the observations throwing light on these suggestions.

OBSERVATIONS

Escape of RHDV off Wardang Island in September 1995
RHD escaped from quarantine on Wardang Island in September 1995, and the first outbreaks on the adjoining mainland were observed the following month (Kovaliski 1998). The distribution of new RHD outbreaks, and the areas receiving above average rainfall, in October 1995 are shown in Fig. 1. Most of the RHD outbreaks occurred in areas near Plumbago and the Flinders Ranges National Park that received unusually heavy (>80 percentile) rainfall. This raised the question, was there a causal connection between these outbreaks and rainfall, and, if so, what was the underlying mechanism?
The weather conditions associated with the movement of RHDV from Wardang Island to the area around Plumbago and the Flinders Ranges National Park are unclear (Wardhaugh and Rochester 1996). Fig. 2 shows the low-pressure system that produced most of the rainfall shown in Fig. 1b (for example, at Yunta – near Plumbago – it produced 2, 6 and 34mm on 20, 21 and 22 October respectively). The presence of RHD in the area around Plumbago and the Flinders Ranges National Park was not confirmed until 28 October, but circumstantial and unconfirmed reports suggest it may have been present in both areas in mid-October, before this low developed. If this is true, RHDV must have been transported to these areas before the low shown in Fig. 2 developed, but this low may then have resulted in the regional dispersal of virus already in the area and the intensification of RHD epizootics to the point that they were noticed and brought to the attention of the authorities. However, if these unconfirmed reports are in error, it is possible that RHDV was both transported to the Plumbago–Flinders Ranges area and disseminated by the system that produced the rainfall on 20–22 October.

Fig. 1. (a) the location of RHD outbreaks for October 1995, and (b) South Australian rainfall percentiles for the same month.

Small low-pressure systems producing rainfall and centred near a disease outbreak would appear to have the potential to spread virus present either as an aerosol or on a vector. Cloud cover would reduce degradation by ultraviolet light, and high humidity could lengthen the time the virus survived outside a host. The virus could be transported into the atmosphere by the ascending air associated with low pressure systems, be transported radially by atmospheric convergence or divergence, and be returned to ground level by downdrafts generated by heavy rainfall or, in the case of vector-borne virus, by the flight of the vector. In addition to movement generated by air circulation within the low-pressure system, movement of the system as a whole could potentially transport viral particles large distances before their return to earth. A low pressure system centred over Australia would be...
less likely to transport an airborne virus offshore than one centred south of Australia, which is the more common position of the low pressure systems affecting southern Australia.

Could this provide a plausible meteorological mechanism for other long-distance movements of RHDV apparent in the early history of RHD outbreaks? The hypothesis that there was a causal connection between the long-distance dispersal of RHD and low-pressure systems would be supported if other examples could be found where the occurrence of new RHD outbreaks in areas remote from previous outbreaks was correlated with the presence of low-pressure systems and heavy rainfall. Several long-distance movements of RHD occurred in the year following the escape of RHD off Wardang Island (see maps in Kovaliski 1998), and one of these will be considered below.

**Appearance of RHD in central Victoria in March 1996**

Eleven RHD outbreaks occurred near Bendigo in central Victoria in March 1996, several hundred kilometres from other known occurrences of virus (see Fig. 3a). The first was reported on 1 March 1996, the second on the 6th and the remainder from the 19th to the end of the month. RHD kills rabbits within 1–4 days of infection (Cooke and Berman 2000; Cooke 2002), so the virus must have spread to Victoria in February 1996 or earlier. Above average rainfall occurred in the same area in February (Fig. 3b) and in January (not shown). One candidate weather system is shown in Fig 4a; this produced heavy rainfall (43mm in total) at Bendigo on 27 and 28 February. However, it is doubtful if this system could have transported sufficient virus hundreds of kilometres to produce noticeable mortality as soon as 1 March, or to produce 11 noticeable outbreaks in one small area near Bendigo without producing outbreaks in other areas as well. It is more plausible to suggest that a small amount of virus was transported by an earlier weather system to establish a single, unnoticed, outbreak near Bendigo, which was amplified and spread over the surrounding area by subsequent systems to produce a more noticeable epizootic.

**Fig. 3.** (a) the location of RHD outbreaks for March 1996 (solid triangles are new outbreaks for the month and open circles are earlier outbreaks), and (b) rainfall percentiles for February 1996.

The level of RHD outbreaks in Australia was low over the 1995/1996 summer (Kovaliski 1998), with ten outbreaks in December 1995, eight in January 1996, and only one in February 1996. It is therefore possible that the disease arrived in the Bendigo area some weeks before March 1996 and persisted at a low level, without causing noticeable mortality, until conditions improved. Such improvement may have been provided by rain that fell in February 1996, as this was largely confined to Victoria (see Fig 3b), the only part of Australia where RHD outbreaks occurred in March 1996. Rainfall in eastern Australia in January 1996...
was more widespread, and fell in some areas where RHD had previously occurred apparently without causing new outbreaks (data not shown). In this case RHDV may have been carried to the Bendigo area by low pressure systems on 8–9 February (28mm rain at Bendigo) (data not shown), or 31 December 1995/1 January 1996 (47mm rain at Bendigo) (Fig. 4b), with the outbreaks noticed in March being generated by the favourable conditions accumulating from the 8–9 and 27–28 February systems. The system shown in Fig. 4b tracked across RHD-infected areas in South Australia and then over central Victoria.

![Synoptic weather maps](image)

**Fig. 4.** Synoptic weather maps for (a) 26 and 27 February 1996 and (b) 30 December 1995 to 1 January 1996.

**DISCUSSION**

Though not conclusive, the evidence presented here supports the existence of an association between the observation of major dispersal events of RHD, low-pressure systems and above average rainfall. However, a closer examination of the meteorological data associated with these observations suggests that the processes underlying them proceed in two stages, the first being a relatively inconspicuous dispersal event whose timing may be uncertain, and the second a more noticeable local/regional intensification and multiplication of outbreaks in response to heavy rainfall associated with a low pressure system centred nearby. The probability that the stage 1 transport of virus to the outbreak area is affected by a similar weather system as well is unclear, but given the apparent capacity of stage 2 events to produce multiple new outbreaks, this possibility cannot be discounted.

Rainfall has the capacity both to return airborne micro-organisms to earth, and possibly to create conditions favourable for the proliferation of some potential insect vectors in the same area. The association of some dispersal events with heavy rainfall suggests that mosquitoes may be involved as a vector, a possibility also considered by Wardhaugh and Rochester (1996) in relation to the October 1995 outbreaks. The mosquito *Culex annulorostris* can transmit RHDV under laboratory conditions (Cooke 2002).
The hypothesis that RHDV may have been transported by low-pressure systems will be tested by modelling air parcel movement for relevant systems to establish whether plausible meteorological mechanisms exist for the long-distance transport of RHDV by these systems. In addition, it may be possible to infer whether the virus was transported on insects or as an aerosol from a study of the air temperatures and wind speeds associated with the putative movements and an understanding of the meteorological and other requirements for airborne movement of the various candidate organisms.

The work has the potential to contribute to our understanding of the epidemiology of RHD, but it may also have wider implications. An understanding of the interaction between weather and the movement of animal diseases over long distances has relevance for contingency planning for exotic disease control, for the establishment of appropriate conditions for confining new candidate biocontrol agents under quarantine while they are being field tested prior to their release, and for the understanding of the epidemiology of any disease spread by flying vectors or aerosols.

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REFERENCES


