The dynamic landscape of bat borne zoonotic viruses in Australia

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This review discusses the history, epidemiology, diagnostics, clinical presentation in humans, as well as control and prevention measures, of the high-profile viruses Hendra virus (HeV) and Australian bat lyssavirus (ABLV). Since the discovery of HeV and ABLV in the 1990s, these viruses have only caused disease in areas where spill-over hosts, including humans, encounter the reservoir host.

Bats

Australia is home to over 90 species of bats, covering many different habitats. All but eight species belong to the suborder Microchiroptera (microbats). See Table 1 for a list of the eight species from the suborder Megachiroptera (megabats) found on mainland Australia, four of which belong to the genus Pteropus (commonly called flying foxes or fruit bats). Figure 1 provides a link to an interactive map showing flying fox camps in Australia.

The distribution of bats in Australia has changed over time. As their habitats are destroyed, many have been forced to adapt to life on the urban fringe. There are many successful flying fox camps in the heart of large and smaller cities across Australia – Brisbane, Sydney, Melbourne, Geelong and Cairns to name a few. In the past 10 years, we have seen the southern limit of the black flying fox (Pteropus alecto) distribution extend further south, and the south-western limit of the grey headed flying fox (Pteropus poliocephalus) distribution extend across into South Australia as well. By contrast, the very small footprint of the spectacled flying fox (Pteropus conspicillatus) in far north Queensland, is predicted to get even smaller over time⁴. The black flying fox will most likely fill this void. The ecological drivers behind these changes are complex but are highly likely to include loss of natural habitat, changes to food availability and warming climates.

Hendra virus

Since it was first described in Australia in 1994, HeV has caused horse and human illness and deaths. A high prevalence of neutralizing antibodies to HeV in bats of the genus Pteropus, and the isolation of Hendra virus from the same genus, confirmed flying foxes as reservoir hosts for this virus². All four species of pteropus bats can be infected (Table 1). From recent work it appears that the risk of a spill-over event is greatest when either the black flying fox or the spectacled flying-fox is present³. The reservoir host appears to co-exist with this virus in complete harmony. The virus spreads easily amongst flying-foxes with the HeV seroprevalence in flying-fox colonies fluctuating over time and geography. The theory of viral co-evolution with chiropteran hosts has been previously suggested, and all field observations and experimental evidence to date supports this hypothesis⁴. Figure 1 provides a link to the results of Hendra virus research conducted in Australia, as well as information for horse owners.

Figure 2 compares the routes of transmission for HeV and ABLV and other closely related bat viruses which result in human infection. For HeV, horses are the main spill-over host and serve as amplifying hosts, capable of infecting humans. The disease in horses exhibits seasonality with more spill-over events occurring in winter. Since it was discovered in 1994, only 95 horses have died to date. Horses in paddocks where flying foxes either roost or come to feed, are at risk of exposure to infection. Infection in horses most likely occurs after close contact with bat urine and birthing material which contain sufficiently high titres of virus to infect a horse¹⁵.

Extreme care must be taken in the handling of samples collected for HeV diagnostic testing. HeV is a Biosafety level four (BSL4) agent, in
Table 1. Megachiropteran bats, all belonging to the family Pteropodidae, found on mainland Australia. One common name for each is listed, noting that some have several common names. The last two columns highlight whether evidence of infection with HeV or ABLV has been found in that species.

<table>
<thead>
<tr>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
<th>Common name(s)</th>
<th>HeV</th>
<th>ABLV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subfamily Pteropodinae</td>
<td>Dobsonia</td>
<td>Dobsonia magna</td>
<td>Bare-backed Fruit Bat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subfamily Pteropodinae</td>
<td>Pteropus</td>
<td>Pteropus alecto</td>
<td>Black Flying-fox</td>
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<td>✓</td>
</tr>
<tr>
<td>Subfamily Pteropodinae</td>
<td>Pteropus</td>
<td>Pteropus conspicillatus</td>
<td>Spectacled Flying-fox</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Subfamily Pteropodinae</td>
<td>Pteropus</td>
<td>Pteropus poliocephalus</td>
<td>Grey-headed Flying-fox</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Subfamily Pteropodinae</td>
<td>Pteropus</td>
<td>Pteropus scapulatus</td>
<td>Little Red Flying-fox</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Subfamily Macroglossinae</td>
<td>Macroglossus</td>
<td>Macroglossus minimus</td>
<td>Lesser Long-tongued Fruit Bat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subfamily Macroglossinae</td>
<td>Syconyteris</td>
<td>Syconycteris australis</td>
<td>Queensland Blossom Bat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subfamily Nyctiminae</td>
<td>Nyctimene</td>
<td>Nyctimene robinsoni</td>
<td>Queensland Tube-nosed Bat</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

USEFUL RESOURCES
CLICK ICON TO ACCESS WEBSITES WITH INFORMATION

- ABLV Bats Stats: A six-monthly report prepared by the WHA Bat Health Focus Group presenting information on ABLV testing in bats.
- Flying Fox Camp Census: An interactive flying-fox web viewer that presents camp census data collected via the National Flying-fox Monitoring Program.
- Horse Owner Information: Advice for horse owners who want to reduce the risk of Hendra virus infection in their horses from the Qld government.
- National Hendra Virus Research: Compendium of findings from 20 projects under the National Hendra Virus Research Program, 2016.
- Bat FAQ: Answers to questions about flying foxes and possible impacts on human health from NSW Department of Health.

glycoprotein of Hendra virus is very immunogenic and affords protection against HeV challenge in experimental infections. Since the vaccine was released, no vaccinated horse has been diagnosed with Hendra virus infection. Vaccination of horses provides a public health and workplace health and safety benefit by reducing the risk of HeV transmission from horses to humans and other susceptible animals. Whenever HeV infection is suspected, even in vaccinated horses, appropriate biosecurity precautions, including personal protective equipment (PPE), should be used by all people in contact with sick horses.

**ABLV**

In 1996 a five-month-old female black flying fox was found under a fig tree in Wollongbar, NSW, unable to fly. From this bat, a virus with close serologic and genetic relationships to members of the Lyssa-virus genus of the family Rhabdoviridae was isolated. ABLV has since been found in all four flying fox species and in one species of microbat, the yellow-bellied sheath-tailed bat. It is assumed that all Australian bat species have the potential to carry and transmit ABLV. ABLV is transmitted to humans by bites or scratches from an infected bat.

No laboratory tests are currently available to diagnose ABLV in humans before the onset of clinical disease. In the early stages of disease, saliva and cerebrospinal fluid (CSF) can be tested by PCR. Antibody testing can also be performed on CSF. A positive serum antibody test is diagnostic of lyssavirus infection provided the person has never been immunised against rabies and may assist in the diagnosis of lyssavirus clinical disease. Any negative test on a symptomatic person is not definitive, as viral shedding in body secretions is intermittent and early tests may be negative for antibody. Therefore, repeat testing is often indicated.

For post mortem testing in humans and animals including bats, the standard diagnostic techniques include positive fluorescent antibody test (FAT) and PCR on fresh brain smears, and PCR from tissues.

ABLV infection has resulted in three human deaths, two adults and an eight-year-old child, in Queensland, Australia; 1996, 1998 and 2013. Transmission from flying foxes and an insectivorous microbat were implicated, with all three cases displaying features of encephalitic (furious) rabies before their demise. The incubation period is thought to mirror rabies (usually 3–8 weeks, but potentially as short as a few days or as long as several years). Exposure through wounds close to the central nervous system on the head and neck or richly innervated areas like the fingers, carry an increased infection risk and may result in a shorter incubation period. In furious rabies, prodromal symptoms may precede sensorineural dysfunction, with progression to hyperactivity, aero-phobia and/or hydrophobia, followed by convulsions. The clinical
course following symptom onset is usually rapid, almost invariably progressing to death within a few days.

Regarding prevention, the key strategy is for untrained and unvaccinated people to avoid handling bats. Public health authorities promote this message particularly during periods of high bat activity, including fruiting periods, and heat stress events when bats and especially pups drop to the ground. Prompt post-exposure vigorous wound cleaning, submission of the bat’s brain for ABLV testing (where possible), rabies vaccination and administration of rabies immunoglobulin, are recommended following bat bites or scratches. Figure 1 provides a link to statistics on ABLV surveillance in Australia, as well as answers to questions about flying foxes and possible impacts on human health from NSW Department of Health.

**Conclusions**

ABLV and HeV can both cause an encephalitis syndrome in humans, sometimes with significant delay or recrudescence. Bats are the reservoirs of these viruses and may well be implicated in transmission of yet to be identified zoonotic pathogens. As the distribution of these reservoir hosts changes, so too does the risk of spill-over events that may involve humans.

**Conflicts of interest**

The authors declare no conflicts of interest.

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**References**


**Biographies**

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**David Durrheim** is Conjoint Professor of Public Health Medicine, University of Newcastle, and Director - Health Protection, Hunter New England Health. He is a Public Health Physician with an established track record in conducting research that has an operational focus and is translational in nature. Professor Durrheim is an outspoken advocate for equitable global access to effective public health measures, particularly immunisation. He has been instrumental in developing novel surveillance systems to detect and facilitate response to emerging infectious disease risks.