Herpesviruses in Australian marsupials

Fact Sheet

December 2023

Key points

- Wildlife, including Australian marsupials, may be hosts to a range of herpesviruses.
- Herpesvirus infections are usually lifelong and benign, producing no clinical effects in their hosts.
- Occasionally, infection is associated with significant mortality or clinical disease, often when a herpesvirus moves into a new host species or the host is stressed.
- Although there is a broad understanding of the behaviour of herpesviruses in wildlife, there is limited specific knowledge of the effects of a given herpesvirus on primary or incidental hosts.

Aetiology

Herpesviruses (HV) are enveloped DNA viruses. The family *Herpesviridae* is divided into three subfamilies: *Alphaherpesvirinae*, *Betaherpesvirinae* and *Gammaherpesvirinae*. Alpha- and gammaherpesviruses have been mostly widely studied in Australian marsupials [1].

One health implications

Wildlife and the environment: herpesvirus infections appear to be common in both captive and wild marsupials and are generally considered benign. Negative impacts on wild populations may occur when naïve or immunocompromised hosts are infected, resulting in disease.

Domestic animals: alphaherpesviruses (AH) are known to cause several significant diseases in domestic animals e.g. *Bovine alphaherpesvirus 1*, *Equid alphaherpevirus 1*, *Canid alphaherpesvirus 1*. It is unknown whether AH found in Australian marsupials could infect or cause disease in domestic species.

Humans: it is not known whether HV found in Australian marsupials can infect humans. Some AH have zoonotic potential, although these specific viruses have not been found in marsupials.

Natural hosts

Herpesviruses have been found in a range of native marsupials including macropods, potoroos, wombats, koalas (*Phascolarctos cinereus*), dasyurids, gliders, bandicoots and bilbies. Six AH have been isolated from marsupials: *Macropodid alphaherpesvirus 1* (MaHV-1), *Macropodid alphaherpesvirus 2* (MaHV-2) and four novel species. Nineteen gammaherpesviruses (GH) have been isolated from Australian marsupials: *Phascolarctid gammaherpesvirus 1* (PhaHV-1), and 18 novel species (Appendix 1). Herpesvirus has also been found in the short-beaked echidna (*Tachyglossus aculeatus*) [2].

World distribution and occurrences in Australia

Herpesviruses are found worldwide and cases of HV have been reported in captive macropods in the USA and in NZ [2-4]. Marsupial HV have been reported Australia-wide with all marsupial species assumed to be susceptible to infection [5].

Epidemiology

Once infected with a HV, an animal remains infected for life. The virus generally lies dormant within host cells ("latent" infection), until infection is reactivated by factors such as stress or immune compromise [6]. During the "lytic" (active) phase, the virus replicates within the host cell, and releases a new generation of viruses when the infected host cell lyses (is destroyed). The viral infection can be transmitted to other individuals during the lytic phase.

Alphaherpesviruses have a moderately wide host range, rapid growth, lyse infected cells and have the capacity to establish latent infections mainly in sensory nerve ganglia. Betaherpesviruses (BH) have a more restricted host range, a long replicative cycle, the capacity to cause infected cells to enlarge and the ability to form latent infections in secretory glands, lymphoreticular tissue, kidneys and other tissues. Gammaherpesviruses have a narrow host range, replicate in lymphoid cells, may induce neoplasia in infected cells and form latent infections in lymphoid tissue [7, 8].

Herpesviruses may be shed from various parts of the body. Transmission of HV generally requires close contact such as mating, licking, nuzzling or sneezing, resulting in aerosol spread over short distances. Virus has been found in nasal swabs of eastern grey kangaroos (*Macropus giganteus*) [6] and cloacal swabs of tammar wallabies (*M. eugenii*).

Antibodies to HV are widespread and prevalent in both captive and wild populations of marsupials but seroprevalence may be higher in captive populations [2]. Seroprevalence may increase with the age of the animal [9]. High levels of seroprevalence to a HV in a host species indicate that the host species is likely a natural host for that HV and disease is unlikely to manifest unless the host is stressed [10]. However, cross-reactivity between types of HV means testing accuracy may be poor [11]. An overall MaHV-1 and MaHV-2 seroprevalence of 40% has been demonstrated in a survey of five different marsupial families [12]. Prevalence of HV infection can vary between species and populations, with high HV DNA prevalence detected in the eastern grey kangaroo, swamp wallaby (*Wallabia bicolor*), koala, Tasmanian devil (*Sarcophilus harrisii*) and common wombat (*Vombatus ursinus*) [9, 12].

Herpesviruses do not commonly cause significant disease in the primary host. Occasionally, infection is associated with significant mortality or clinical disease if the host is stressed or if certain types of HV move from a natural host species into a different host species. Situations that foster abnormal host mixing, or stress in the host provide for increased risk of HV associated disease. In Australian marsupials, clinical disease is more commonly described in captive animals, most likely due to observational opportunities.

In koalas, the presence of both PhaHV-1 and *Phascolarctid gammaherpesvirus 2* (PhaHV-2), has been strongly associated with concurrent infection with *Chlamydia pecorum*, although the nature of this association remains unclear [9, 12]. Similar significant associations has been observed between *Macropodid gammaherpesvirus 6* (MaHV-6) and *Theileria* sp. infection in quokkas (*Setonix brachyurus*) [13]. Associations between PhaHV-1 and koala retrovirus (KoRV) [9], *Macropodid gammaherpesvirus 3* (MaHV-3) infection and mammary neoplasia [4] and HV infection and poor body condition [12] have also been suggested.

Herpesviruses are fragile and do not survive well outside the body. They are killed by all common disinfectants including bleach and F10 (benzalkonium chloride/polyhexamethylene biguanide hydrochloride).

Clinical signs

Latent HV infections cause no clinical signs. Lytic infections (often during times of stress, concurrent infection or immune compromise) can cause disease and mortality outbreaks. Clinical signs associated with HV infections include sudden death, depression, fever, incoordination, conjunctivitis, increased respiratory sounds and vesicles and ulcers on the oral mucosa, cloaca and penis [14]. Signs of disease associated with HV infection have been reported in several Australian marsupial species (Appendix 2).

Diagnosis

Diagnosis of clinical disease in the live animal is largely dependent on presence of typical signs, in particular if the individual has recently had a history of stress or concurrent disease. However no clinical signs are uniquely diagnostic for HV infections in and across marsupial species [1]. There are currently no commercial diagnostic tests for HV diagnosis in a clinical setting [15].

PCR is useful for antemortem diagnosis and molecular classification of infections. Swabs can be collected from conjunctivae, nasal mucosa, oropharynx and cloaca [5]. The presence of the virus is not confirmatory of a disease process. A PCR-positive animal can be assumed to have a lifelong HV infection.

A serum neutralisation test can detect antibodies against MaHV-1, MaHV-2 and *Macropodid alphaherpesvirus 4* (MaHV-4) in the live animal. Exposure to other related AH may result in cross-reactions [11]. As many marsupials have antibodies to HV, paired samples with a rising titre are required to demonstrate active infection.

A loop-mediated isothermal amplification (LAMP) assay has been developed as a point-of-care test for PhaHV-1 [16].

While PCR and serological testing detects an animal's exposure to HV infections, these tests are unable to differentiate between latent and lytic infection [1].

Electron microscopy may useful in identifying the virus particles from tissue samples [1]. Virions have been found in the prostate of an infected antechinus [17] and in the lung of infected bilbies [18].

At necropsy, multifocal hepatic necrosis together with intranuclear inclusion bodies is suggestive of disease due to HV infection. These characteristic histopathological changes have been detected in the respiratory tract, liver and adrenal gland of an infected koala [19] This can be confirmed through electron microscopy, viral culture or PCR [1, 14].

Pathology

Typical histopathological changes include inflammation and necrosis along with intranuclear inclusion bodies, often in the liver, spleen, lymph nodes, and respiratory and genitourinary tract [1]. Post mortem lesions can include mucoid tracheitis, pulmonary congestion and pneumonia and pale foci in the liver, corresponding to multifocal areas of necrosis. Diphtheritic plaques can be found on the oesophageal and gastric mucosa and focal ulceration and necrosis of the genitalia may also occur. Inclusion bodies are also found on occasion in affected areas of skin and mucosa [5].

Histologic lesions consistent with HV infections have been seen in the liver, spleen and prostrate of two antechinus species, including areas of necrosis and intranuclear inclusion bodies [17]. Similar necrotising lesions, intranuclear inclusion bodies, pulmonary and hepatic congestion have been found in the respiratory tract of bilbies infected with AH [18]. A koala infected with a novel AH was found to have necrotising lesions in the respiratory tract, adrenal gland and liver [19]. Due to the nature of HV infections it can be difficult to determine whether pathology can be attributed to the HV infection or is due to another disease process.

Differential diagnoses

Differential diagnoses for MaHV-1 to -4 include macropod diseases associated with sudden death, such as toxoplasmosis and encephalomyocarditis virus infection, diseases causing hepatic necrosis, such as yersiniosis and salmonellosis and diseases causing mucosal ulceration, such as *Treponema spp.* infection [20]. There is no clear differential diagnosis for other novel AH and GH found in other marsupial species.

Treatment, prevention and control

Treatment is largely through supportive care. There are no reports of use of antiviral compounds for antemortem treatment in marsupials [1].

It is important that captive populations are monitored for disease associated with HV and that the HV status of populations is known. If populations are vulnerable to new exposures, appropriate biosecurity should be maintained, including quarantine, hygiene, testing and minimising stressors and concurrent disease.

In free-ranging wildlife populations it is useful to know the HV status and understand underlying factors contributing to HV susceptibility or spread [1]. With translocation of native species and captive breeding for release, there is risk that HV might be introduced into naïve populations.

Maintaining HV-free captive populations will be difficult, given the high prevalence of HV in many marsupial species. Significant clinical disease and mortality outbreaks have generally been associated with periods of stress, primary exposure of immunologically naïve individuals or in novel host species, which should be considered in the management of captive or free-living macropods.

Research

Key areas of future research include:

- further surveys to determine the distribution and prevalence of HV in wild and captive marsupial populations [19]
- determining how infection is acquired [21]
- understanding the relationship between infection and clinical disease and the impact of infection at a population level, particularly to already vulnerable populations
- exploring possible treatment options
- investigating the possible interactions and role that HV plays with other diseases, and the factors responsible for these associations [15]
- determining the origin of HV when newly detected in marsupial species
- the implications and management of HV in re-introduction programs
- determining whether wild populations are at risk from HV in captive populations [22].

Surveillance and management

Wildlife Health Australia administers Australia's general wildlife health surveillance system, in partnership with government and non-government agencies. Wildlife health data is collected into a national database, the electronic Wildlife Health Information System (eWHIS). Information is reported by a variety of sources including government agencies, zoo based wildlife hospitals, sentinel veterinary clinics, universities, wildlife rehabilitators, and a range of other organisations and individuals. Targeted surveillance data is also collected by WHA. See the WHA website for more information https://wildlifehealthaustralia.com.au/Our-Work/Surveillance and https://wildlifehealthaustralia.com.au/Our-Work/Surveillance/eWHIS-Wildlife-Health-Information-System. We are interested in hearing from anyone with information on this condition in Australia, including laboratory reports, historical datasets or survey results that could be added to the National Wildlife Health Information System. Negative data are also valuable. If you can help, please contact us at admin@wildlifehealthaustralia.com.au.

Cases of HV detection in kangaroos, wallabies, pademelons, koalas, bandicoots, antechinus, bilbies and bettongs have been reported to the National Wildlife Health Information System.

Appendix 1: Herpesvirus species found in Australian marsupials and monotremes

Note: there is the potential of cross-reactivity with other uncharacterised herpesviruses

C = captive individual; W = wild individual;
*= serology;
#= PCR;
** seroprevalence study did not distinguish between MaHV-1 detection and MaHV-2 detection

Herpesvirus species	Australian marsupial hosts	Individual status	References
Alphaherpesviruses			
Macropodid alphaherpesvirus 1 (MaHV-1)	Parma wallaby*	C and W	Webber and Whalley 1978 [2]
	Red-necked pademelon*	W	
	Red-legged pademelon *	W	
	Spectacled hare wallaby *	W	
	Rock wallabies*	C and W	
	Eastern wallaroo*	C and W	
	Western wallaroo*	C and W	
	Eastern grey kangaroo*	W	
	Long-nosed potoroo*	W	
	Bandicoots*	W	
	Short-beaked echidna*	C and W	
	Tammar wallaby*	C	
	Red kangaroo*	C	
	Antechinus*	C	
	Crest-tailed mulgara*	C	
	Western grey kangaroo*	W	Kerr et al. 1981 [10]
	Quokka*	W	Martínez-Pérez et al. 2021 [13]
	Lumholtz's tree-kangaroo*	C	Shima et al. 2020 [22]
	Brush-tailed bettong*	C	Skogvold et al. 2017 [23]
Macropodid alphaherpesvirus 2 (MaHV-2)	Lumholtz's tree-kangaroo *	C	Shima et al. 2020 [22]
	Brush-tailed bettong*	C	Skogvold et al. 2017 [23]
	Quokka*	C and W	Martínez-Pérez et al. 2021 [13], Wilks et al. 1981 [24]
Macropodid alphaherpesvirus 1 (MaHV-1) or Macropodid alphaherpesvirus 2 (MaHV-2)**	Eastern grey kangaroo*	W	Stalder et al. 2015 [12]
	Swamp wallaby*	W	
	Tasmanian devil*	C and W	
	Common wombat*	W	
	Eastern bettong*	W	Portas et al. 2014 [25]
	Brush-tailed rock wallaby*	C and W	Schultz et al. 2011 [26]
Macropodid alphaherpesvirus 4 (MaHV-4)	Eastern grey kangaroo#, Lumholtz's tree-kangaroo#	C and W	Vaz et al. 2013 [11], Shima et al. 2020 [22]
Phascolarctid alphaherpesvirus 3 (PhaHV-3)	Koala#	C	Bowater et al. 2022 [19]
Vombatid alphaherpesvirus 3 (VoHV-3)	Common wombat#	W	Stalder et al. 2015 [12]
Undesignated alphaherpesvirus	Greater bilbies#	C	Besier et al. 2016 [18]
Gammaherpesviruses			
Macropodid gammaherpesvirus 3 (MaHV-3)	Eastern grey kangaroo#, western grey kangaroo#	C and W	Smith et al. 2008 [4], Douch et al. 2022 [21], Wilcox et al. 2011 [27]
Macropodid gammaherpesvirus 5 (MaHV-5)	Swamp wallaby#	W	Stalder et al. 2015 [12]
Macropodid gammaherpesvirus 6 (MaHV-6)	Quokka#	W	Martínez-Pérez 2016 [28]
Phascolarctid gammaherpesvirus 1 (PhaHV-1)	Koala#	W	Vaz et al. 2011 [29]
Phascolarctid gammaherpesvirus 2 (PhaHV-2)	Koala#	W	Vaz et al. 2012 [30]

Vombatid gammaherpesvirus 1 (VoHV-1)	Wombat#	W	Stalder et al. 2015 [12]
Vombatid gammaherpesvirus 2 (VoHV-2)	Wombat#	W	Stalder et al. 2015 [12]
Dasyurid gammaherpesvirus 1 (DaHV-1)	Yellow-footed antechinus#, agile antechinus#	W	Amery-Gale et al. 2014 [17]
Dasyurid gammaherpesvirus 2 (DaHV-2)	Tasmanian devil#	C and W	Stalder et al. 2015 [12]
Dasyurid gammaherpesvirus 3 (DaHV-3)	Tasmanian devil, eastern quoll#	C and W	Chong et al. 2019 [31], Portas et al. 2020 [32]
Dasyurid gammaherpesvirus 4 (DaHV-4)	Eastern quoll#, yellow-footed antechinus	W	Douch et al. 2022 [21], Harvey et al. 2023 [33]
Dasyurid gammaherpesvirus 5 (DaHV-5)	Yellow-footed antechinus	Unknown	Harvey et al. 2023 [33]
Potoroid gammaherpesvirus 1 (PotHV-1)	Eastern bettong#, brush-tailed bettong#	W	Skogvold et al. 2017 [23], Portas et al. 2014 [25]
Peramelid gammaherpesvirus 1 (PeHV-1)	Southern brown bandicoot#	W	Stalder et al. 2015 [12]
Peramelid gammaherpesvirus 2 (PeHV-2)	Northern brown bandicoot#	W	Langhorne et al. 2021 [34]
Leadbeater's possum gammaherpesvirus (LPHV)	Leadbeater's possum#	W	Douch et al. 2022 [21]
Yellow-bellied glider gammaherpesvirus (YBGHV)	Yellow-bellied glider#	W	Douch et al. 2022 [21]
Lumholtz's tree-kangaroo gammaherpesvirus (LtkHV)	Lumholtz's tree kangaroo#	C and W	Shima et al. 2020 [22]
Undesignated gammaherpesvirus	Northern quoll#, northern brown bandicoot#	W	Reiss et al. 2015 [35]
Unknown herpesviruses			
	Rufous bettong Brush-tailed bettong Red kangaroo Common wombat	C C C C	Dickson et al. 1980 [36] Britt et al. 1994 [3] Rothwell et al. 1988 [37]

Appendix 2: Signs of disease associated with herpesvirus infection in Australian marsupials

* Seroprevalence study did not distinguish between MaHV-1 detection and MaHV-2 detection

Herpesvirus species	Australian marsupial hosts	Signs of disease	References
Alphaherpesviruses			
Macropodid alphaherpesvirus 1 (MaHV-1)	Parma wallaby Tammar wallaby	Fever, conjunctivitis, vesicles, ulcers, rhinitis, pneumonia, incoordination, respiratory rales, mortality Incoordination, respiratory rales, conjunctivitis, ulcers, mortality	Acland 1981 [38], Finnie et al. 1976 [39] Webber and Whalley 1978 [2]

Macropodid alphaherpesvirus 2 (MaHV-2)	Quokka	Conjunctivitis, vesicles, ulcers, mortality	Callinan and Kefford 1981 [40]
Macropodid alphaherpesvirus 1 (MaHV-1) or Macropodid alphaherpesvirus 2 (MaHV-2)*	Brush-tailed rock wallaby	Lesions	Schultz et al. 2011 [26]
Macropodid alphaherpesvirus 4 (MaHV-4)	Eastern grey kangaroo Lumholtz's tree kangaroo	Respiratory disease, rhinitis, conjunctivitis, neurological signs Respiratory disease, discharge, lethargy, mortality	Vaz et al. 2013 [11] Shima et al. 2020 [22]
Phascolarctid alphaherpesvirus 3 (PhaHV-3)	Koala	Anorexia, respiratory disease, lethargy, dyspnoea	Bowater et al. 2022 [19]
Undesignated alphaherpesvirus	Greater bilbies	Respiratory disease, nasal discharge, lethargy, mortality	Besier et al. 2016 [18]
Gammaherpesviruses			
Macropodid gammaherpesvirus 3 (MaHV-3)	Eastern grey kangaroo Western grey kangaroo	Ulcers, cloacitis, respiratory disease, discharge, lethargy, respiratory rales, fever, inappetence, ataxia, mortality Not described	Smith et al. 2008 [4], Wilcox et al. 2011 [27] Douch et al. 2022 [21]
Phascolarctid gammaherpesvirus 1 (PhaHV-1)	Koala	Lymphoid depletion, conjunctivitis	Vaz et al. 2011 [29], Stephenson 2021 [41]
Phascolarctid gammaherpesvirus 2 (PhaHV-2)	Koala	Lymphoid depletion	Vaz et al. 2012 [30]
Dasyurid gammaherpesvirus 1 (DaHV-1)	Yellow-footed antechinus, agile antechinus	Infection within the prostate	Amery-Gale et al. 2014 [17]
Dasyurid gammaherpesvirus 3 (DaHV-3)	Eastern quoll	Ulcers	Portas et al. 2020 [32]
Lumholtz's tree-kangaroo gammaherpesvirus (LtkHV)	Lumholtz's tree kangaroo	Mild respiratory disease	Shima et al. 2020 [22]
Unknown herpesviruses			
	Brush-tailed bettong Rufous bettong Red kangaroo Common wombat	Mortality Mortality Non-specific illness, mortality Lethargy, inappetence, mortality	Dickson et al. 1980 [36] Britt et al. 1994 [3] Rothwell et al. 1988 [37]

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Wildlife Health Australia recognises the Traditional Custodians of Country throughout Australia. We respectfully acknowledge Aboriginal and Torres Strait Islander peoples' continuing connection to land, sea, wildlife and community. We pay our respects to them and their cultures, and to their Elders past and present.

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References and other information

1. Devlin J and Stalder K (2019) Marsupial herpesviruses. In 'Current Therapy in Medicine of Australian Mammals.' (Eds V. L and T. Portas) pp. 353. (CSIRO: Collingwood, Vic)
2. Webber CE and Whalley JM (1978) Widespread occurrence in Australian marsupials of neutralizing antibodies to a herpesvirus from a parma wallaby. *Australian Journal of Experimental Biology and Medical Science*, **56**: 351-357
3. Britt JO, Frost DF et al. (1994) Fatal herpesviral hepatitis in a red kangaroo (*Macropus rufus*). *Journal of Zoo and Wildlife Medicine*: 580-584
4. Smith JA, Wellehan JF et al. (2008) Identification and isolation of a novel herpesvirus in a captive mob of eastern grey kangaroos (*Macropus giganteus*). *Veterinary Microbiology*, **129**(3): 236-245
5. Vogelnest L and Portas T (2008) Macropods. In 'Medicine of Australian mammals.' pp. 133-225. (CSIRO Publishing)
6. Guliani S, Smith GA et al. (1999) Reactivation of a macropodid herpesvirus from the eastern grey kangaroo (*Macropus giganteus*) following corticosteroid treatment. *Veterinary Microbiology*, **68**(1): 59-69
7. Lachlan N and Dubovi E (2011) Herpesvirales. In 'Fenner's Veterinary Virology.' pp. 179-201. (Elsevier: London)
8. Roizman B and Pellett P (2001) The family *Herpesviridae*: a brief introduction. In 'Fields Veterinary Virology.' pp. 2381-2397. (Lippincott Williams & Wilkins: Philadelphia)
9. Vaz PK, Legione AR et al. (2019) Detection and differentiation of two koala gammaherpesviruses by use of high-resolution melt (HRM) analysis reveals differences in viral prevalence and clinical associations in a large study of free-ranging koalas. *Journal of Clinical Microbiology*, **57**(3): e01478-18
10. Kerr A, Whalley J et al. (1981) Herpesvirus neutralising antibody in grey kangaroos. *Australian Veterinary Journal*, **57**(7): 347-348
11. Vaz PK, Motha J et al. (2013) Isolation and characterization of a novel herpesvirus from a free-ranging eastern grey kangaroo *(Macropus giganteus*). *Journal of Wildlife Diseases*, **49**(1): 143-151
12. Stalder K, Vaz PK et al. (2015) Prevalence and clinical significance of herpesvirus infection in populations of Australian marsupials. *PLoS One*, **10**(7): e0133807
13. Martínez-Pérez P, Hyndman TH et al. (2021) A widespread novel gammaherpesvirus in apparently healthy wild quokkas (*Setonix brachyurus*): a threatened and endemic wallaby of western Australia. *Journal of Zoo and Wildlife Medicine*, **52**(2): 592-603
14. Ladds P (2009) 'Pathology of Australian Native Wildlife.' (CSIRO Publishing: Melbourne)
15. Vitali SD, Reiss AE et al. (2023) National Koala Disease Risk Analysis - Appendices version 1.2. Available from: https://doi.org/10.25910/gfg9-vk76%20
16. Wright BR, Jelocnik M et al. (2023) Development of diagnostic and point of care assays for a gammaherpesvirus infecting koalas. *PLOS ONE*, **18**(6): e0286407
17. Amery-Gale J, Vaz PK et al. (2014) Detection and identification of a gammaherpesvirus in Antechinus spp. in Australia. *Journal of Wildlife Diseases*, **50**(2): 334-339
18. Besier A, Mahony T et al. (2016) Alphaherpesvirus-associated disease in greater bilbies (*Macrotis lagotis*). *Australian Veterinary Journal*, **94**(6): 208-212
19. Bowater R, Horwood P et al. (2022) A novel alphaherpesvirus and concurrent respiratory cryptococcosis in a captive koala (*Phascolarctos cinereus*). *Australian Veterinary Journal*, **100**(7): 329-335

20. Vaughan-Higgins R, Buller N et al. (2011) Balanoposthitis, dyspareunia, and treponema in the critically endangered Gilbert's potoroo (*Potorous gilbertii*). *Journal of Wildlife Diseases*, **47**(4): 1019-1025

21. Douch J, Devlin J et al. (2022) Molecular detection of two new putative species of gammaherpesvirus in petaurid possums. *Australian Veterinary Journal*, **100**(11): 562-565

22. Shima AL, Vaz PK et al. (2020) Herpesvirus infection in Lumholtz's tree-kangaroo (*Dendrolagus lumholtzi*). *Journal of Wildlife Diseases*, **56**(4): 912-917

23. Skogvold K, Warren KS et al. (2017) Infectious disease surveillance in the Woylie (*Bettongia penicillata*). *EcoHealth*, **14**: 518-529

24. Wilks C, Kefford B et al. (1981) Herpesvirus as a cause of fatal disease in Australian wallabies. *Journal of Comparative Pathology*, **91**(3): 461-465

25. Portas T, Fletcher D et al. (2014) Health evaluation of free-ranging eastern bettongs (*Bettongia gaimardi*) during translocation for reintroduction in Australia. *Journal of Wildlife Diseases*, **50**(2): 210-223

26. Schultz DJ, Rich BG et al. (2011) Investigations into the health of brush-tailed rock-wallabies (*Petrogale penicillata*) before and after reintroduction. *Australian Mammalogy*, **33**(2): 235

27. Wilcox R, Vaz P et al. (2011) Gammaherpesvirus infection in a free-ranging eastern grey kangaroo (*Macropus giganteus*). *Australian Veterinary Journal*, **89**(1-2): 55-57

28. Martínez-Pérez P (2016) Health and disease status in a threatened marsupial, the quokka (*Setonix brachyurus*). thesis, Murdoch University

29. Vaz P, Whiteley P et al. (2011) Detection of a novel gammaherpesvirus in koalas (*Phascolarctos cinereus*). *Journal of Wildlife Diseases*, **47**(3): 787-791

30. Vaz P, Whiteley PL et al. (2012) Detection of a second novel gammaherpesvirus in a free-ranging koala (*Phascolarctos cinereus*). *Journal of Wildlife Diseases*, **48**(1): 226-229

31. Chong R, Shi M et al. (2019) Fecal viral diversity of captive and wild Tasmanian devils characterized using virion-enriched metagenomics and metatranscriptomics. *Journal of Virology*, **93**(11): e00205-19

32. Portas TJ, Evans MJ et al. (2020) Baseline health and disease assessment of founder eastern quolls (*Dasyurus viverrinus*) during a conservation translocation to mainland Australia. *Journal of Wildlife Diseases*, **56**(3): 547-559

33. Harvey E, Mifsud JCO et al. (2023) Divergent hepaciviruses, chuvirus and deltaviruses in Australian marsupial carnivores (*Dasyurids*) identified through transcriptome mining. *bioRxiv*: 2023-06

34. Langhorne C, Sullivan J et al. (2021) Identification and prevalence of a gammaherpesvirus in free-ranging northern brown bandicoots (*Isoodon macrourus*). *Journal of Wildlife Diseases*, **57**(4): 912-916

35. Reiss A, Jackson B et al. (2015) Investigation of potential diseases associated with Northern Territory mammal declines - Final report.

36. Dickson J, Hopkinson W et al. (1980) Herpesvirus hepatitis in rat kangaroos. *Australian Veterinary Journal*, **56**(9): 463-464

37. Rothwell J, Canfield P et al. (1988) Death due to a probable herpesvirus infection in a common wombat (*Vombatus ursinus*). *Australian Veterinary Journal*, **65**(11): 360-361

38. Acland H (1981) Parma wallaby herpesvirus infection. *Journal of Wildlife Diseases*, **17**(3): 471-477

39. Finnie E, Littlejohns I et al. (1976) Mortalities in parma wallabies (*Macropus parma*) associated with probable herpesvirus. *Australian Veterinary Journal*, **52**(6): 294-294

40. Callinan R and Kefford B (1981) Mortalities associated with herpesvirus infection in captive macropods. *Journal of Wildlife Diseases*, **17**(2): 311-317

41. Stephenson T (2021) Pathology, coinfections and oncogenesis in South Australian koalas (*Phascolarctos cinereus*) and their association with koala retrovirus (KoRV). PhD thesis, University of Adelaide: Adelaide, South Australia

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