Transactions of the Royal Society of Tropical Medicine and Hygiene 2026; **0:** 1–11
https://doi.org/10.1093/trstmh/trag077
Published: 0 2026
Original article

Ethno-etiology meets virology: land leeches (family: *Haemadipsidae*) as potential disease vectors

Thomas S. Kraft [1,*], **Vivek V. Venkataraman** [2], **Michael Gurven** [3], **Mohd Nazip Suratman** [4], **Tony L. Goldberg** [5]

[1]Department of Anthropology, University of Utah, 260 S Central Campus Dr, Salt Lake City, UT 84112, United States
[2]Department of Anthropology and Archaeology, University of Calgary, 2500 University Dr. N.W.. Calgary, AB T2N 1N4, Canada
[3]Department of Anthropology, University of California, Santa Barbara, HSSB 2001, Santa Barbara, CA 93106-3210, United States
[4]Faculty of Applied Sciences, Universiti Teknologi MARA, Blok C, Kompleks Sains 2, 40450 Shah Alam, Selangor Darul Ehsan, Malaysia
[5]Department of Pathobiological Sciences, School of Veterinary Medicine, University of Wisconsin-Madison, 2015 Linden Drive, Madison, WI 53706, United States
*Corresponding author. E-mail: thomas.kraft@utah.edu

Abstract

Objectives **Hematophagous terrestrial leeches are common in rainforest habitats and widely regarded as pests. Despite limited research, circumstantial evidence raises the possibility that, beyond being an annoyance, terrestrial leeches could potentially transmit diseases.**

Methods **We explored this possibility using multiple approaches. First, we reviewed published literature to synthesize knowledge related to disease transmission by leeches. Second, we collected terrestrial leeches (genus *Haemadipsa*) from human-occupied rainforests in Peninsular Malaysia and applied metagenomic methods for virus discovery to their anterior segments. Finally, we conducted interviews to probe local knowledge and behavior related to leeches, testing whether cultures may encode information that recognizes and helps to prevent vector-borne disease transmission.**

Results **Results indicate that terrestrial leeches are potential disease vectors, particularly via mechanical vector-borne transmission stimulated by human removal techniques. Supporting this, we identified four novel viruses within leeches, three of which are distantly related to medically important animal and human viruses which could potentially be transmitted among animal species, including humans. However, ethno-etiological evidence suggests that local Indigenous cultures do not recognize land leeches as disease vectors or promote behaviors likely to reduce transmission, suggesting knowledge may not encompass difficult-to-observe vectors.**

Conclusion **We conclude that disease transmission by terrestrial leeches is plausible and merits experimental study.**

Accession numbers: **PX094876, PX118495, PX118496, PX118497, PX118498, PX118499**

Keywords *Haemadipsidae*, Orang Asli, Peninsular Malaysia, traditional ecological knowledge, virus

Introduction

On the East Indies Station, one is made to realize that this land leech can be not only an annoyance, but even a positive danger… The Royal Naval Camp, Diyatalawa, Ceylon… lies in typical leech country… Within a few hours of our arrival, casualties began to report. One rating dozed for ten minutes on the ground, and returned in a state of panic with numerous black bodies hanging from his neck; another woke one morning to find himself bleeding severely from the groin and scrotum. Firing parties on the open range were the chief victims, being attacked while marching to and from their destination, and finding it almost impossible to lie down and shoot owing to the attacks of leeches. In fact, when walking about the surrounding country one had to possess not only the usual snake-sense, but also leech-sense." -JLS Coulter[1]

Leeches are segmented worms (phylum: Annelida, class: Clitellata) with a global distribution spanning aquatic and terrestrial habitats. Many leech species are hematophagous, feeding serially on blood extracted from parasitized hosts using either proboscis-like mouthparts to pierce the skin or semicircular rows of teeth arranged on muscular ridges to make an incision.[2] Blood-sucking leeches identify hosts using a range of stimuli including vibrations, movement, carbon dioxide, and heat,[3] and, once attached, use chemical anticoagulants (especially the peptide hirudin) from unicellular salivary glands to encourage continued blood flow.

Received: 12 September 2025. **Revised:** 13 April 2026. **Accepted:** 12 June 2026

Although Coulter's passage indicates serious disquiet about the highly visible effects of terrestrial (land) leeches, he was likely unconcerned about the potential of leeches to transmit disease to humans. Whereas disease transmission has long been of interest concerning aquatic leeches,[4] especially *Hirudo medicinalis* and other leeches with a long history of use in medicine,[5] only recently have scientists begun to examine the potential for terrestrial leeches to serve as important mammalian disease vectors. There are several potential reasons for this discrepancy.

First, publications dating back to the mid-twentieth century have long suggested that terrestrial leeches do not transmit pathogens to human hosts.[6–10] For example, in summarizing the military significance of terrestrial leeches, Wilson and Eisenberg[10]:2 noted that, "… unlike the other invertebrates mentioned, leeches are not known to transmit infectious agents to man." Second, most terrestrial leeches, especially those within the family *Haemadipsidae*, occur mainly in the tropical and subtropical rainforests of Australia, Indo-Pacific islands, and South/Southeast Asia,[11] world regions that are home to a large number of neglected vector-borne diseases. Third, even in endemic countries, urban human populations rarely encounter terrestrial leeches due to their primary occurrence in humid rainforest. Leeches are highly susceptible to desiccation in the dry open habitats that are characteristic of well-populated built environments.[3]

Claims that leeches do not transmit pathogens remain widespread today on the internet (e.g. Fig. 1) and among nature guides operating in leech-infested areas (T. Kraft, personal observations). Indeed, some authors have even suggested that beliefs about the inability of terrestrial leeches to transmit disease may account for the paucity of research on these species.[12]:18 However, despite little direct study of terrestrial leeches, their potential role as disease vectors is heightened when considering that the relevant physiology is similar to that of aquatic leeches. For example, Shope[4] conducted an experimental study designed to determine how long viruses could persist in the digestive tracts of aquatic leeches (*Hirudo medicinalis*), permitting transmission events. He tested this proposition by feeding leeches on pigs and rabbits infected with hog cholera virus and myxoma virus, and found that leeches retained living viruses for periods of up to 87 and 154 days after infective blood meals, respectively. Importantly, in three cases, Shope also documented direct transmission events of hog cholera virus to susceptible swine hosts in the process of normal feeding up to 34 days after infective blood meals. Because experiments failed to reveal the viral presence in leech tissues outside of gut contents, Shope concluded that leeches must have introduced infectious blood via regurgitation into lesions made during feeding.

Later studies confirmed these findings. Using microscopy, Nehili *et al*.[13] observed that bacteriophages and bacteria persisted for up to 6 months in the guts of experimentally infected medical leeches (*Hirudo medicinalis*) and that protozoan parasites continued to survive and reproduce for up to 5–6 weeks in the gut. Other studies have similarly found that a variety of mammalian viruses survived and remained infectious within leeches for long periods at different temperatures,[14] even when ingested viral concentrations were low.[15] Although pathogen entry into the salivary glands (which would allow for direct transmission) was not observed,[13] thus supporting Shope's inference,[4] other studies have shown that, in at least some cases, aquatic leeches are responsible for the regular transmission of hemogregarine parasites of fish and

Figure 1 Example of a popular portrayal of leech removal and the general belief that leeches do not transmit disease. Figure from online website: https://www.artofmanliness.com/skills/outdoor-survival/how-to-remove-a-leech/.

reptiles and blood parasites such as *Trypanoplasma*.[16] Evidence of HIV I, HIV II, and hepatitis B in free-living aquatic leeches from Cameroon[13] further suggests that it is common for aquatic leeches to naturally harbor human pathogens.

Less research is available on terrestrial leeches. Nevertheless, the potential role of these species as disease vectors has attracted increasing attention, including from the US military following observations of the physical consequences (blood loss and secondary infections resulting from bites) and psychological effects that leeches have had on combat troops serving in tropical regions.[8–10] (Note that multiple authors have commented on the fear elicited by land leeches, particularly due to beliefs about potential invasion of the penile urethra,[10] with some troops purportedly resorting to wearing condoms for protection while sleeping.[6] Unsurprisingly, such paranoia regarding leeches leads to notable decreases in combat efficiency.[9]) To the best of our knowledge, direct transmission of disease from land leeches to humans or other species has never been observed. However, supporting lines of evidence are accumulating. For example, a land leech

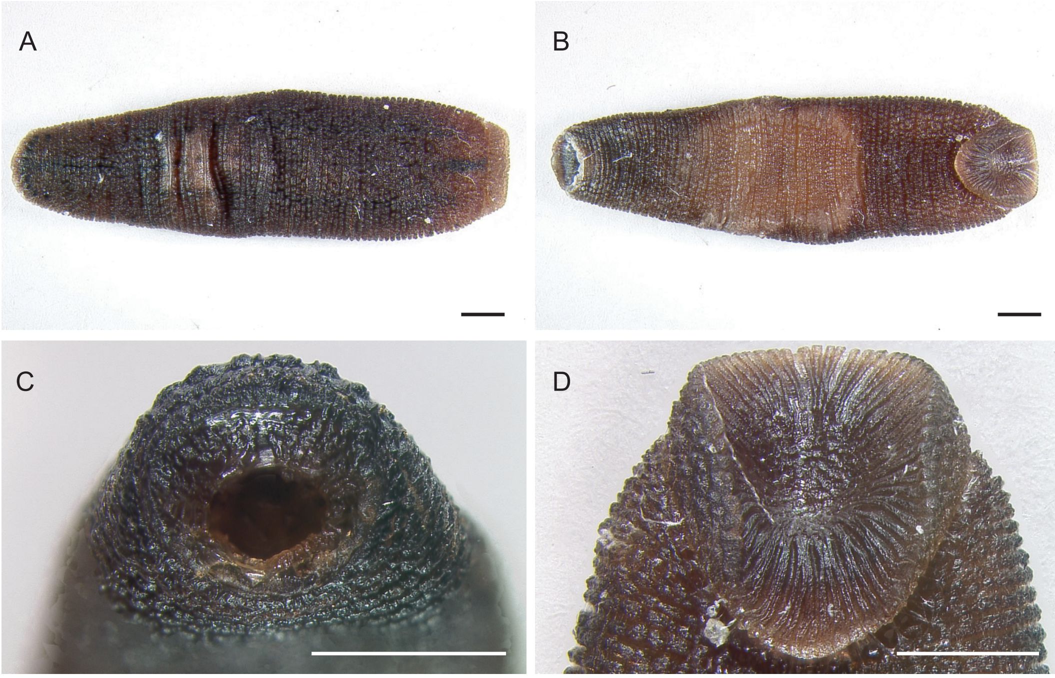

Figure 2 Images of a land leech of the genus *Haemadipsa* from Peninsular Malaysia. A: dorsal, B: ventral, C: mouthparts, D: sucker. Images were captured using a KY-F75U digital camera (JVC, Yokohama, Japan) attached to a Z16 APO dissecting microscope (Leica Microsystems, Wetzlar, Germany) affixed with gooseneck illuminators (Ace 1, Schott Corporation, San Diego, CA, and Intralux 5000–1, Volpi Group, Schlieren, Switzerland) and assembled from 15 stacked layers with a patch size of 16 using Auto Montage Pro software v5.01.005 (Synoptics LTD, Cambridge, UK) at 1.0x magnification (A, B) or 3.2x magnification (C, D). White conglomerates are artifacts (crystallized salts from RNAlater preservation buffer). Scale bars = 1 mm.

(*Haemadipsida* spp.) bite was implicated in a 2008 case study of rickettsial infection in Laos,[17] similar to a case of rikettsiosis reported in Chile following a bite from a different terrestrial leech species.[18] Likewise, Kang *et al*.[19] used molecular techniques to establish the presence of *Bartonella* bacteria in hematophagous land leeches from Korea (*Haemadipsa rjukjuana*) that were confirmed to have fed on a variety of species, including humans, mice, weasels, and birds. Finally, a recent study using terrestrial leech-derived "iDNA" in Malaysian Borneo used metagenomic techniques to confirm that land leeches harbor a wide diversity of viruses, making these species a potentially important tool for zoonotic disease surveillance.[20] Because land leeches feed serially on a range of species in tropical rainforests including birds, mammals (including bats), reptiles, and amphibians,[21,22] cross-species transmission is plausible, especially for humans, due to the use of removal techniques that incite regurgitation of past blood meals.[17]

Human behavior plays an additional role in determining the likelihood that vector-borne pathogens are transmitted. Potentially protective behaviors include knowledge of and avoidance of vector-infested areas, the use of technological or pharmacological deterrents, and culturally prescribed actions that reduce the probability of transmission (e.g. mandating isolation of sick individuals, food taboos). It is therefore possible that local cultures have developed traditional ecological knowledge that can be both highly functional and potentially indicative of novel disease vectors. In the case of terrestrial leeches, we hypothesized that local peoples may exhibit culturally prescribed practices or knowledge that favor removal techniques which decrease the likelihood of disease transmission. This conceptual framework brings together "ethno-etiology," which investigates culturally grounded theories of the causes of illness[23,24] and virology. Specifically, we examine the understandings, beliefs, practices, and behaviors of human populations that have had long-term exposure to and interaction with land leeches and whether belief systems in these populations align with data from molecular virology.

To explore the potential of terrestrial leeches as disease vectors, this study poses two questions. First, do land leeches harbor viruses relevant to zoonotic disease transmission? We focus on viruses because they are the type of pathogen most likely to emerge and cause epidemics or pandemics,[25] although our approach could easily be adopted for other pathogen types (e.g. bacteria or eukaryotic parasites). To be viable viral vectors, leeches would need to (i) reliably harbor known mammalian viruses; (ii) maintain those viruses for long enough to facilitate host-to-host contact; and (iii) be capable of transmitting those viruses between hosts. Second, using an ethno-etiological approach, we ask whether local human populations maintain traditional knowledge, practices, and beliefs that indicate awareness of terrestrial leeches as a potential source of disease transmission.

Materials and methods

Sample collection

A small sample of leeches (n=7; Fig. 2) were collected in two forested locations in Peninsular Malaysia that are both subject to human traffic, including tourists as well as local Indigenous populations (Fig. 3). Researchers found leeches by walking on established trails, pausing intermittently to look for signs of move-

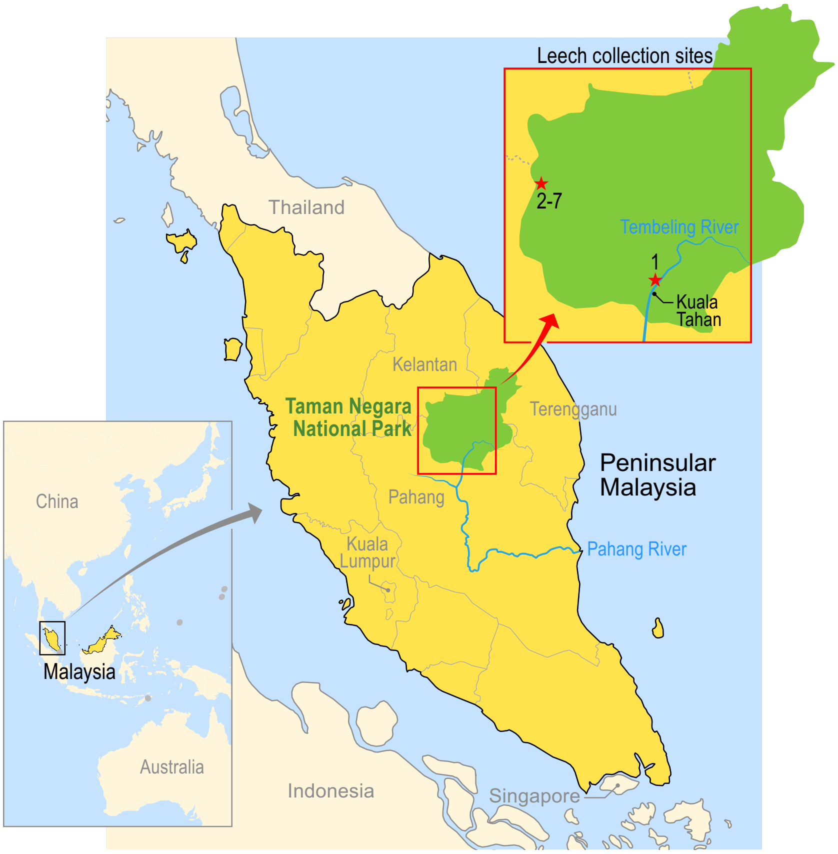

Figure 3 Map of leech collection sites.

ment. Once spotted, leeches were immobilized using forceps sterilized with 70% ethanol and placed into RNAlater solution (Qiagen, Hilden, Germany) in a sterile tube. Care was taken to prevent leeches touching any human materials that could introduce contamination.

Processing and analysis

Leeches were processed using methods previously described for virus identification in hematophagous arthropods.[26–29] Leeches were first surface-sterilized using dilute bleach followed by three rinses with nuclease-free water to remove external contaminants.[30] The posterior two-thirds of each leech was then removed using a sterile razor blade and the anterior third was processed further, to favor detection of viruses associated with leech mouthparts and other anatomic features associated with hematophagy. The anterior third of each leech was then homogenized in PowerBead tubes with 2.38 mm metal beads (Qiagen, Hilden, Germany) containing Hank's balanced salt solution (HBSS) using five 30-s cycles in an orbital homogenizer (Minibeadbeater, BioSpec Products, Bartlesville, OK, USA).

For genetic identification, DNA was extracted from 50 µl of leech homogenate using DNeasy Blood & Tissue Kit (Qiagen). A segment of the cytochrome oxidase subunit 1 (cox1) gene was then amplified by PCR with barcoding primers LCO1490 (5′-GGTCAACAAATCATAAAGATATTGG-3′) and HC02198 (5′-TAAACTTCAGGGTGACCAAAAAATCA-3′)[31] and the HotStarTaq system (Qiagen). Amplicons were visualized under ultraviolet light after electrophoresis on 1% agarose gels stained with ethidium bromide, then Sanger sequenced on ABI 3730xl sequencers (Thermo Fisher Scientific, Waltham, MA, USA) at a commercial facility (Functional Biosciences, Madison, WI, USA).

For virus characterization, 250 µl of leech homogenate was centrifuged and gently digested with nucleases to reduce non-encapsidated genetic material.[27–29] Total nucleic acids were then extracted and libraries were prepared using the Nextera XT DNA kit (Illumina, San Diego, CA, USA), and libraries were sequenced on a MiSeq instrument (V3 chemistry, 600 cycle paired-end; Illumina) as previously described.[27 - 29]. Resulting sequences were trimmed to a quality (Phred) score of $\geq$Q30 and length $\geq$50 using CLC Genomics Workbench (Qiagen), and reads of known contaminants, ribosomal sequences, and the *Helobdella robusta* reference genome (GenBank GCF_000326865.2) were subtracted in silico. Sequences remaining after contaminant and host removal were then subjected to de novo assembly using metaSPAdes v.3.15.5,[32] and resulting contigs $\geq$400 nt were compared with the NCBI non-redundant (nr) protein database using 6-frame translation, implemented with DIAMOND.[33] Putative viral hits were then verified manually by using ORF finder[34] and blastn and blastp.[35] For further verification and examination of non-viral sequences, all raw reads and contigs were queried against the NCBI nr database using blastx.[36] VirusSeeker[37] was used to examine all assigned and unassigned reads, and unassigned reads were examined manually. Finally, reads from each sample were mapped to each virus contig, and a metagenomic measure of virus read density (log10 virus reads per million per kilobase of target, which correlates with quantitative real-time PCR data[38]) was calculated. Leeches with a value >1 were classified as positive for a virus.

Indigenous knowledge of terrestrial leeches

The second question of our study is whether the Indigenous populations of Malaysia, having lived alongside terrestrial leeches for thousands of years, have developed cultural practices or beliefs that would recognize terrestrial leeches as a potential disease reservoir and potentially help prevent disease spread. The Orang Asli, meaning “original people” in the Malay language, are descendants of the first inhabitants of Peninsular Malaysia and consist of 19 distinct ethnolinguistic groups.[39] The Orang Asli speak either Austroasiatic or Austronesian languages and have traditionally practiced varied lifeways that include hunting and gathering, small-scale shifting horticulture, and trade of jungle products. Despite ongoing development and market integration in the modern Malaysian context, many Orang Asli today continue to occupy peripheral areas that stimulate regular interaction with terrestrial leeches among all members of society. For more detail on the ethnohistory and lifestyles of the Orang Asli, we refer readers to Carey[40] and Endicott.[39]

Given prior evidence suggesting a higher likelihood of transmission due to regurgitation during the terrestrial leech removal process, a primary focus of our research was on techniques for removing a leech once attached to the skin. Specifically, we conducted semi-structured interviews with an opportunistic sample of Orang Asli individuals (including both men and women) from two groups that regularly interact with leeches and have a long history of occupation of prime leech habitats: Batek (hunter-gatherers inhabiting interior regions of lowland rainforest) and Temiar (small-scale horticulturalists living in hilly and mountainous areas). Interviews were conducted in a one-on-one setting in either the Batek language or Bahasa Malaysia, and notes were recorded at the time of interview. Our semi-structured interviews included the following general questions:

- Describe/demonstrate the “right” or “acceptable” way to remove a leech that has not yet drawn blood.
- Describe/demonstrate the “right” or “acceptable” way to remove a leech that is already full with blood.
- Are there any taboos regarding behavior towards leeches?
- Is it acceptable to remove an engorged leech by burning it with fire? If not, why?
- Is it acceptable to remove an engorged leech by putting salt on it? If not, why?
- Can the bite of a leech spread disease or give you illness? If yes, what types of disease/illness?

In addition, we also analyzed ethnographic texts and queried Orang Asli ethnographers about their observations and understanding of Indigenous techniques regarding leech removal and related cultural taboos. Because leeches are a common feature of Peninsular Malaysian rainforests, it is common for ethnographies of the Orang Asli to include references to leeches and nearly all ethnographers have direct experience in observing interactions between Orang Asli and leeches.

Permissions and approvals

All protocols were approved by the Malaysian Ministry of Economic Affairs and Department of Wildlife and National Parks Peninsular Malaysia (UPE 40/200/19/3577).

Results

Viral identification

DNA barcoding was successful for three leeches, with cox1 sequences being 99.7% identical to *Haemadipsa interrupta* in one case and 97.25% and 97.44% identical to *H. trimaculosa* in the other two cases (GenBank accessions PX057207-PX057209). These results were consistent with the examination of sequence reads generated using metagenomics, which identified *H. interrupta*, although this same analysis also identified sequences matching *H. robusta* (likely due to high representation of *H. robusta* in GenBank databases).

Analysis of metagenomic data (Sequence Read Archive accession PRJNA1301424; BioSample accessions SAMN50444817-SAMN50444823) for viruses identified six viruses (GenBank accessions PX094876 and PX118495-PX118499), five of which are novel, as evidenced by <48% amino acid sequence identity to known viruses (Table 1). For convenience, the five novel viruses were named using the common identifier “Malhaem” to indicate their origin in Malaysia in leeches of the genus *Haemadipsa*. Three of the viruses identified belong to genera known to infect mammals, including humans. Human mastadenovirus C (*Adenoviridae*: *Mastadenovirus*) was present in five of seven leeches, a virus related to mink coronavirus (*Coronaviridae*: *Alphacoronavirus*) was present in one leech, and a virus related to tilapia rhabdovirus 2 (Rhabdoviridae: Scophrhavirus) was present in one leech (Table 1). The remaining three viruses (Malhaem viruses 3, 4, and 5) are related to viruses that infect non-mammalian hosts, including fish, mosquitoes, and snails (Table 1). Contigs were generally short, so their taxonomic placement should be considered preliminary.

Indigenous perspectives on land leeches and disease

Multiple Batek individuals provided consistent answers during semi-structured interviews. Specifically, no individuals believed that leeches carry or transmit human diseases. Itching at the site of leech bites was cited as the main harmful result. Regarding removal, it was said that proper removal techniques include using a small stick to flick a leech off, although many methods can be used if a leech is well attached, including both burning with fire or the application of salt. No individuals explicitly said that it was not acceptable to use fire or salt when asked directly. Removal methods were said to be used without regard to the engorgement status of a leech (pre- vs post-blood meal). Similarly, several Temiar informants stated that the normal method for removal is to use the fire from a rolled tobacco cigarette to burn leeches.

There are two discernible leech taboos among Batek that we confirmed through interviews. The first is that it is considered taboo (“*lawac*”) to consume, laugh at, or generally show emotions towards a leech. The second was described as prohibiting the burning of leeches in cooking fires (despite the general use of fire being acceptable). Both of these beliefs have been previously well documented,[41]: 637–1,[42,43] and extend to other Orang Asli populations.[44–46] : 22 For the Jahai, for example, leech removal is similarly performed with minimal attention-drawing behavior and laughing at leeches is tabooed (Jahai: *hmɨɲ*; N. Berenhult, personal communication). Leeches also appear to be viewed by most Orang Asli as generally unclean; considering food taboos,

Table 1 Viruses in land leeches from Peninsular Malaysia.

Virus	Abbreviation	Contig length (nt)	Coverage[a]	Accession[b]	Closest match (host, location, year, accession)[c]	Genome[c]	Family[c]	Genus[c]	E-value[c]	% ID (aa)[c]	Prevalence (%)[d]
Human mastadenovirus C	Ad-C	679	3.46	PX094876	Human mastadenovirus C (human, Viet Nam, 2015, AAA96406)	dsDNA (linear)	*Adenoviridae*	*Mastadenovirus*	2E-161	100	71.4
Malhaem virus 1	MALHV-1	701	2.56	PX118495	Mink coronavirus 1 (mink, Denmark, 2015, QKX95788)	+ssRNA	*Coronaviridae*	*Alphacoronavirus*	3E-18	32.90	14.3
Malhaem virus 2	MALHV-2	423	2.58	PX118496	Tilapia rhabdovirus 2 (fish, Gabon, 2019, YBW54404)	-ssRNA	*Rhabdoviridae*	*Scophrhavirus*	7E-37	51.15	14.3
Malhaem virus 3	MALHV-3	851	3.02	PX118497	Inshore hagfish bafinivirus (Hagfish, Japan, 2011, DBA44882)	+ssRNA	*Tobaniviridae*	*Bafinivirus*	3E-49	39.53	14.3
Malhaem virus 4	MALHV-4	1305	5.52	PX118498	Aedes albopictus densovirus (mosquito, Australia, u, AYH52679)	ssDNA (linear)	*Parvoviridae*	*Brevihamaparvovirus*	7E-46	34.72	14.3
Malhaem virus 5	MALHV-5	1661	5.01	PX118499	Nidogavirus pomacea11307 (apple snail, China, u, DBA49310)	RNA	unclassified	unclassified	7E-138	44.42	14.3

[a] Sequence coverage averaged across all leeches positive for a virus.
[b] GenBank accession number of viral sequence from this study.
[c] Closest match (u=unspecified), genome composition, family, genus, E-value, and % identity (amino acid, to the closest match) identified by querying the deduced amino acid sequence of the longest open reading frame on each contig against the NCBI non-redundant (nr) protein database using blastp.
[d] Percentage of leeches (n=7) in which reads mapping to a virus sequence were detected.

Bolton[47]: 791 wrote that "Small lizards and leeches are considered to be unclean by the deep jungle Orang Asli. If a leech accidently drops into a cooking pot, all the contents of the pot are regarded as contaminated and are rejected."

The ethnographers we surveyed reported observations in agreement with the Indigenous accounts above. For example, a researcher working with Jahai hunter-gatherers in the state of Perak reported having never observed the use of fire or salt in the removal of leeches. Instead, Jahai are said to use a machete or other blade to scrape an attached leech off the skin, sometimes chopping it up afterwards (J. Weinstock, personal communication). Likewise, one of the authors (TSK) has observed Batek foragers deftly using a "scrape, roll, and flick" motion that overcomes the propensity for a leech to resist removal. Consistent with reports from the Batek themselves, two ethnographers (L. Tuck-Po and K. Endicott, personal communication) reported the common use of fire, including from cigarettes, lighters, or embers from a fire. One ethnographer of the Temiar (G. Benjamin, personal communication) said the use of a lighted cigarette to burn attached leeches was the most common method of removal. Interestingly, the Temiar apparently consider it obligatory to burn a leech once it has been carried into a house on a person or their clothing, as opposed to being removed and thrown into the open again.[48]

Overall, Indigenous Malaysians appear to use a variety of methods for land leech removal, including fire, with little concern. There are no reported accounts of cultural avoidance or prohibitions against burning leeches. As described by Robarchek,[49]: 297 "Certainly none of my Semai acquaintances ever voiced any such fear [of leeches]. I would suggest that those who cope with the leech on a daily basis are all too familiar with its habits to hold such a view. Everyone knows that the leech bites, drinks its fill, and falls off." Nonetheless, the consistency of beliefs prohibiting certain behaviors around leeches and their perception as unclean does indicate a special recognition with the potential to alter human–leech interactions, albeit one that does not extend to particular removal methodologies.

Discussion

To assess the potential for terrestrial leeches to be viable vectors of zoonoses, we synthesize existing evidence to revisit the questions posed above: Do land leeches (i) harbor mammalian viruses, bacteria, protozoa, or other known pathogens; (ii) retain living pathogens for long enough to facilitate host-to-host transmission; and (iii) have a mechanism by which pathogens could consistently transmit between hosts?

Do terrestrial leeches harbor mammalian viruses and other pathogens?

Despite limitations in generalizability due to the small sample size of leeches analyzed, our results show that land leeches harbor viruses that could be of medical concern. Of the six viruses identified in Malaysian land leeches in this study, five are novel, and three are members of genera known to infect mammals, including humans. Our findings are consistent with a larger-scale study using metagenomic techniques to investigate mammalian viruses in two species of land leeches (*Haemadipsa picta* and *Haemadipsa zeylanica*) from Malaysian Borneo[20]; this study found viruses similar to those reported here, including a coronavirus related to MALHV-1 (GenBank QVQ29916.1), rhabdoviruses, and parvoviruses. We note that Alfano *et al*.[20] also conducted blood meal analysis of leeches to infer the mammalian hosts of each virus. Their results revealed that leeches had fed on diverse mammalian taxa native to Deramakot Forest Reserve, which is a protected area of high biodiversity, but they did not identify any human hosts. Our focus on areas frequented by humans, and results showing that many leeches were infected with human mastadenovirus C, support the conclusions of Alfano *et al*.[20] that viruses in leeches reflect the local community of mammals. Our results also suggest that leeches can harbor nucleic acids of viruses known to infect humans.

It remains unclear whether the viruses we identified are infecting and replicating in leeches or were merely acquired through hematophagy or from the environment. The coverage of contigs observed was generally low, whereas high coverage would be expected if viruses were actively replicating in invertebrates.[50] Five of the six viruses identified were present above threshold concentration in only one leech. However, human mastadenovirus C was present in five of seven leeches. The reason for this high prevalence is unclear. It could indicate acquisition of the virus from infected humans or the environment (adenoviruses are non-enveloped with double-stranded DNA genomes and are thus environmentally stable[51]). Alternatively, given that some leeches were collected in the same general area, it could reflect feeding on the same host. However, we cannot discount the possibility of contamination explaining this finding.

Can pathogens survive in terrestrial leeches long enough to reliably facilitate transmission?

Experimental evidence demonstrates that terrestrial leeches are capable of retaining blood meals for up to 8–10 months, with specimens in the lab surviving on only one blood meal per year.[52] Additionally, terrestrial leeches feed on an extraordinary diversity of wildlife[21], will feed prior to the complete digestion of previous blood meals,[9] and it has been experimentally confirmed that viruses readily survive and maintain infectiousness for multiple months after feeding events in the leech gut.[4,15] Perhaps as a result, this study and others[20] find that leeches are a reliable source of viral diversity surveillance. We therefore consider this criterion to be plausible. However, we caution that the detection of pathogens using methods based on the presence of nucleic acids does not guarantee that those pathogens are viable.

Are there mechanisms by which leeches can reliably transmit pathogens between hosts?

Experimental studies in aquatic leeches have confirmed that direct transmission is possible from leeches to mammalian hosts following an infective blood meal.[4] It currently remains unclear, however, whether the viruses identified in terrestrial leeches here or in other studies could be directly transmitted to humans. Although we processed the anterior third of each leech to favor detection of viruses that might be transmitted through mouthparts and related structures involved in the injection of hirudin or other secretions, additional studies are required to investigate whether these viruses are infectious and whether they are shed into salivary secretions.[53]

Regardless of the potential for land leeches to transmit pathogens that are replicating within the host via the salivary gland (biological vector-borne transmission), mechanical vector-borne transmission due to blood regurgitation during feeding and subsequent host blood mixing is likely. If disturbed during a feeding event, leeches are known to regurgitate blood contents in and around the area of incisions.[13] This outcome may be particularly likely for humans, who actively remove leeches using variable methods. Notable removal methods documented in the literature include (i) salt or saline solution; (ii) flame/heat; (iii) the application of tobacco or other chemicals; (iv) grabbing, squeezing, and pulling; (v) scraping a fingernail under the sucker while applying countertraction; and (vi) several others (reviewed in[54]).

We hypothesize that the method of removal plays a role in determining the likelihood of mechanical transmission via regurgitation. Most of the above methods can elicit blood regurgitation of digestive material.[13,54] The use of a scraping motion at the sucker or potentially the application of a mild saline solution, however, are thought to minimize this possibility.[13] Some of the most commonly promoted methods of removal are therefore prone to facilitating a potentially infectious transmission event (Interestingly, early writers were aware of some of these nuances, as demonstrated by this quote from Coulter[1]: "We are always told that on no account should a biting leech be *pulled* off the skin, the reason being given that its head will stay behind. I have not found this to be so in my own experience. I have found that a leech if pulled away can be removed in its entirety, but it is a painful process and a far larger puncture is left in the skin with more troublesome after-haemorrhage. A lighted match or cigarette held to the body causes a leech to release its hold; far better is the application of salt or salt solution which causes it, I strongly suspect, to vomit and consequently fall away.").

Ethno-etiology of land leeches

Given the role of human behavior in facilitating disease transmission from land leeches, we sought to determine Indigenous conceptions of leeches as disease vectors and whether local cultures had developed counter-mechanisms that could minimize transmission risk. For this study, we interviewed Orang Asli living in rural rainforest areas that elicit high exposure to leeches, as well as ethnographers who have lived with and studied these cultures for decades.

Many Orang Asli cultures and other indigenous peoples of Southeast Asia have strong cultural beliefs related to land leeches as part of the so-called "thunder complex."[55,49] These belief systems identify leeches as potentially dangerous animals, such that many human behaviors towards them are subject to taboos governed by supernatural punishment from a powerful thunder god. As noted above, in the well-described case of the Batek, prohibited behaviors include laughing at, showing expression or emotion towards, or eating terrestrial leeches.[41]

We hypothesized that strong cultural beliefs related to leeches might translate to carefully prescribed behaviors related to their removal, with favored techniques being those that are a priori expected to reduce the likelihood of a disease transmission event. We found no evidence to support this idea. Instead, we find repeated evidence for a general nonchalance towards methods of leech removal, including those, such as burning, which are highly likely to encourage blood regurgitation during feeding. If terrestrial leeches are an important reservoir of zoonotic disease, we conclude that we have little evidence of Orang Asli cultures combatting this potential.

A broader question is whether human cultures more generally recognize disease vectors as such and encourage protective behaviors. The answer may be no. For example, a careful study of the Cuiva people of Colombia investigating the mosquito vector revealed that, despite a habitat where mosquitos are likely a major transmitter of diseases that result in illness and mortality, they are not recognized as a transmitter of disease.[56] This finding mirrors work conducted among non-Indigenous populations showing that spatial proximity to disease-affected areas does not necessarily increase perceptions of infectious disease risk.[57] More generally, some have argued that culturally encoded patterns of human behavior often promote the spread of infectious disease,[58] whereas others have identified key ways in which human cultural behaviors stymie outbreaks.[59,60] Taken together, we conclude that it is currently unknown whether human cultures generally contain elements promoting resilience to infectious disease, especially vector-borne diseases.

However, several possibilities remain regarding the potential for local knowledge and practices to be protective. First, it is possible that future experimental evidence will definitively rule out leech-borne transmission of infectious disease, thereby aligning with diverse removal behaviors and a general lack of concern among Orang Asli. This finding would be especially interesting because it would demonstrate the accumulated information embedded in longstanding ethno-etiological systems. Second, Orang Asli beliefs characterizing leeches as dangerous or unclean may themselves elicit behaviors unrelated to removal that discourage interaction with leeches and therefore provide protective benefits. Some anthropologists have argued that beliefs about purity and uncleanliness relate to symbolic systems of order, classification, and social boundary-making, with unclean or taboo objects typically violating or crossing normal boundaries.[61] In addition to being meaningful social tools that manage danger and restore order, such purity beliefs may help motivate the rapid detection and removal of leeches before full attachment by amplifying the normal human disgust response. Future research might fruitfully explore this possibility by deeper investigation of Orang Asli understandings about what leeches do (e.g. taking blood serially from multiple hosts), beliefs regarding zoonotic disease transmission more generally, and whether individuals respond behaviorally to the presence of leeches (e.g. by altering movement patterns in the rainforest based on their expected activity after a rainfall event).

More broadly, a detailed ethno-etiological approach could complement "One Health" initiatives that explicitly recognize interdependencies between the health of people, animals, and the environment. Specifically, recognition and documentation of the cultural factors that structure human responses to infectious disease holds promise for helping to explain epidemiological patterns beyond simplistic attribution to factors such as poverty or deforestation.[62,63] For example, an ethnohistorical study of mpox epidemics in the Central African Republic showed that local populations had limited understanding of the mpox disease, but informants readily identified localized economic and historical changes that have increasingly brought humans into contact with zoonotic reservoirs (i.e. rodents), likely driving increased transmission over time.[63] Likewise, Giles-Vernick *et al*.[64] found that local explanations of illness illuminated the causes of disease risk from Buruli ulcer in Cameroon via consideration not only of ecological change and market reorientation, but also the breakdown of mutual support networks. These examples help explain how Orang Asli perceptions of leeches, even in the absence of direct cultural prescriptions on factors such as removal techniques, have the potential to bolster future biomedical studies of novel vectors.

Conclusions

A broad analysis of existing information, coupled with new evidence presented here, suggests that land leeches satisfy all the necessary conditions to be a vector of zoonotic disease transmission. Namely, in agreement with previous evidence, we identified several new viruses of potential human pathogenicity within the anterior third body segment of land leeches in Peninsular Malaysia, and a growing body of research indicates that terrestrial leeches are both capable of harboring infectious pathogens for long periods of time and interacting with subsequent hosts in a manner that could facilitate transmission events. Despite this potential, however, an ethno-etiological approach considering Indigenous knowledge of and behavior towards terrestrial leeches did not reveal evidence of evolved cultural practices that would provide protection against transmission. Elucidating how human populations with long-term cultural exposure view and act towards disease vectors is a major question for novel research at the interface of anthropology and public health.

Acknowledgements

We gratefully acknowledge the generous insights shared by Orang Asli interviewed for this study, as well as contributions from Orang Asli scholars and members of the Orang Asli Studies group. Special thanks go to Colin Nicholas, Lye Tuck-Po, Geoffrey Benjamin, Kirk Endicott, Justin Weinstock, Edith Mirante, and Niclas Burenhult.

Author contributions

Thomas Kraft (Conceptualization [equal], Data curation [equal], Formal Analysis [equal], Funding acquisition [lead], Investigation [lead], Methodology [equal], Project administration [lead], Visualization [equal], Writing—original draft [lead], Writing—review & editing [lead]), Vivek V. Venkataraman (Investigation [supporting], Writing—review & editing [supporting]), Michael Gurven (Investigation [supporting], Resources [supporting], Writing—review & editing [supporting]), Nazip Suratman (Investigation [supporting], Project administration [supporting], Supervision [supporting], Writing—review & editing [supporting]), and Tony L. Goldberg (Conceptualization [equal], Data curation [supporting], Formal Analysis [equal], Investigation [supporting], Methodology [equal], Supervision [supporting], Visualization [equal], Writing—original draft [supporting], Writing—review & editing [supporting])

Conflicts of interest

The authors declare no competing interests.

Funding

This research was supported by a Cobb Professional Development Grant from the American Association of Biological Anthropologists (to TSK) and by the University of Wisconsin-Madison John D. MacArthur Professorship Chair (to TLG).

Data availability

The data underlying this article are available in GenBank with accession numbers noted in Table 1.

Code availability

Not applicable.

Declaration of Generative AI and AI-assisted technologies in manuscript preparation

None declared.

Ethical approval

All protocols were approved by the Malaysian Ministry of Economic Affairs and Department of Wildlife and National Parks Peninsular Malaysia (UPE 40/200/19/3577).

References

1 Coulter JLS. The land-leech in Ceylon. *J R Nav Med Serv* 1933;19:105–8.
2 Mann KH. *Leeches (Hirudinea): Their Structure, Physiology, Ecology and Embryology*. New York: Pergamon Press, 1962.
3 Phillips AJ, Govedich FR, Moser WE. Leeches in the extreme: morphological, physiological, and behavioral adaptations to inhospitable habitats. *Int J Parasitol: Parasites Wildlife* 2020;12:318–25.
4 Shope R. The leech as a potential virus reservoir. *J Exp Med* 1957;105:373–82.
5 Elliott JM, Kutschera U. Medicinal leeches: historical use, ecology, genetics and conservation. *Freshw Rev* 2011;4:21–41.
6 Harrison J. Leeches. *Med J Malaya* 1953;8:180–5.
7 Smythies B. Leeches of Borneo. *Sarawak Mus J* 1959;9:279–94.
8 Paja S, Varaporn I. *Field Studies on the Effectiveness of Repellents against Terrestrial Leeches in Southern Thailand*, Special Report. no. 465564. Joint Thai-U.S. Military Research and Development Center. Bangkok, Thailand, 1965.
9 Keegan HL, Toshioka S, Suzuki H. *Blood Sucking Asian Leeches of Families Hirudinidae and Haemadipsidae, no. 16*. Biomedical Reports of the 406th Medical Laboratory. Japan: U.S. Army Medical Command, 1968.

10 Wilson HR, Eisenberg G. *Land Leeches of the G. Haemadipsa (Haemadipsoidea: Haemadipsidae) 1. Conditions Essential to Laboratory Colonization*, Lair Institute Report no. 121. D. Presidio of San Francisco, CA: Division of Cutaneous Hazards, Letterman Army Institute of Research, U.S. Army Medical Research & Development Command, 1982.
11 Borda E, Siddall ME. Insights into the evolutionary history of Indo-Pacific bloodfeeding terrestrial leeches (Hirudinida: Arhynchobdellida: Haemadipisdae). *Invertebr Syst* 2011;24:456–72.
12 Lotfy W. Neglected rare human parasitic infections: part IV: hirudiniasis. *Parasitol United J* 2021;14:15–21.
13 Nehili M, Ilk C, Mehlhorn H et al. Experiments on the possible role of leeches as vectors of animal and human pathogens: a light and electron microscopy study. *Parasitol Res* 1994;80:277–90.
14 Al-Khleif A, Roth M, Menge C et al. Tenacity of mammalian viruses in the gut of leeches fed with porcine blood. *J Med Microbiol* 2011;60:787–92.
15 Kampmann ML, Schnell IB, Jensen RH et al. Leeches as a source of mammalian viral DNA and RNA—a study in medicinal leeches. *Europ J Wildlife Res* 2017;9:1–6.
16 Mehlhorn H. *Parasitology in Focus. Facts and Trends*. Berlin: Springer, 1988.
17 Slesak G, Inthalath S, Dittrich S et al. Leeches as further potential vectors for rickettsial infections. *Proc Nat Acad Sci USA* 2015;112:E6593–4.
18 Balcells ME, Rabagliati R, García P et al. Endemic scrub typhus–like illness, Chile. *Emerg Infect Dis* 2011;17: 1659–63.
19 Kang JG, Won S, Kim HW et al. Molecular detection of *Bartonella* spp. in terrestrial leeches (*Haemadipsa rjukjuana*) feeding on human and animal blood in Gageo-do, Republic of Korea. *Parasites Vectors* 2016;9:326.
20 Alfano N, Dayaram A, Axtner J et al. Non-invasive surveys of mammalian viruses using environmental DNA. *Methods Ecol Evol* 2021;12:1941–52.
21 Schnell Ida B, Thomsen PF, Wilkinson N et al. Screening mammal biodiversity using DNA from leeches. *Curr Biol* 2012;22:R262–3.
22 Schnell Ida B, Bohmann K, Schultze SE et al. Debugging diversity—a pan-continental exploration of the potential of terrestrial blood-feeding leeches as a vertebrate monitoring tool. *Mole Ecol Res* 2018;18:1–17.
23 Foster GM. Disease etiologies in non-western medical systems. *Amer Anthropol* 1976;78:773–6.
24 Early EA. The logic of well being: therapeutic narratives in Cairo, Egypt. *Soc Sci Med* 1982;16:1491–7.
25 Cleaveland S, Haydon DT, Taylor L. Overviews of pathogen emergence: which pathogens emerge, when and why? In: Childs JE, Mackenzie JS, Richt JA (eds.), *Wildlife and Emerging Zoonotic Diseases: The Biology, Circumstances and Consequences of Cross-Species Transmission*. Berlin, Heidelberg: Springer, 2007:85–111.
26 Goldberg TL, Bennett AJ, Kityo R et al. Kanyawara virus: a novel rhabdovirus infecting newly discovered nycteribiid bat flies infesting previously unknown pteropodid bats in Uganda. *Sci Rep* 2017;7:5287.
27 Bennett AJ, Paskey AC, Kuhn JH et al. Diversity, transmission, and cophylogeny of ledanteviruses (Rhabdoviridae: Ledantevirus) and nycteribiid bat flies parasitizing Angolan soft-furred fruit bats in Bundibugyo District, Uganda. *Microorganisms* 2020;8:750.
28 Ramírez-Martínez MM, Bennett AJ, Dunn CD et al. Bat flies of the family Streblidae (Diptera: Hippoboscoidea) host relatives of medically and agriculturally important “bat-associated” viruses. *Viruses* 2021;13:860.
29 Kamani J, González-Miguel J, Msheliza EG et al. Straw-colored fruit bats (*Eidolon helvum*) and their bat flies (*Cyclopodia greefi*) in Nigeria host viruses with multifarious modes of transmission. *Vector-Borne Zoonotic Dis* 2022;22:545–52.
30 Binetruy F, Dupraz M, Buysse M et al. Surface sterilization methods impact measures of internal microbial diversity in ticks. *Parasites Vectors* 2019;12:268.
31 Flomer O. DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. *Mol Mar Biol Biotech* 1994;3:294–9.
32 Nurk S, Meleshko D, Korobeynikov A et al. metaSPAdes: a new versatile metagenomic assembler. *Genome Res* 2017;27:824–34.
33 Buchfink B, Xie C, Huson DH. Fast and sensitive protein alignment using DIAMOND. *Nature Methods* 2015;12:59–60.
34 Rombel IT, Sykes KF, Rayner S et al. ORF-FINDER: a vector for high-throughput gene identification. *Gene* 2002;282: 33–41.
35 Altschul SF, Madden TL, Schäffer AA et al. Gapped BLAST and PSI-BLAST: a new generation of protein database search programs. *Nucleic Acid Res* 1997;25:3389–402.
36 Altschul SF, Gish W, Miller W et al. Basic local alignment search tool. *J Molecul Biol* 1990;215:403–10.
37 Zhao G, Wu G, Lim ES et al. VirusSeeker, a computational pipeline for virus discovery and virome composition analysis. *Virology* 2017;503:21–30.
38 Toohey-Kurth K, Sibley SD, Goldberg TL. Metagenomic assessment of adventitious viruses in commercial bovine sera. *Biologicals* 2017;47:64–8.
39 Endicott KM. Introduction. In: Endicott KM (ed.), *Malaysia’s Original People: Past, Present and Future of the Orang Asli*. Singapore: NUS Press, 2016, 1–38.
40 Carey I. *Orang Asli: the Aboriginal Tribes of Peninsular Malaysia*. Kuala Lumpur: Oxford University Press, 1976.
41 Endicott KM. *Batek Negrito Religion: the World-View and Rituals of a Hunting and Gathering People of Peninsular Malaysia*. Oxford: Oxford University Press, 1979.
42 Lye TP. *Batek Hep: Culture, Nature, and the Folklore of a Malaysian Forest People*. M.A.: University of Hawai’i at Manoa, 1994.
43 Rudge A. Laughing when you shouldn’t. *Amer Ethnol* 2019;46:290–301.
44 Evans I. *Studies in Religion, Folk-Lore, and Custom in British North Borneo and the Malay Peninsula*. Cambridge: Cambridge University Press, 1923.
45 Schebesta P. *Die Negrito Asiens 2: Ethnographie Der Negrito, Part 1: Wirtschaft and Soziologie*. Vienna: Modling: St. Gabriel-Verlag, 1954.
46 Dentan RK. *The Semai: a Nonviolent People of Malaya*. New York: Holt, Rinehart and Winston, 1968.
47 Bolton JM. Food taboos among the Orang Asli in West Malaysia: a potential nutritional hazard. *Amer J Clin Nutr* 1972;25:789–99.

48 Benjamin G. *Temiar Religion, 1964-2012: Enchantment, Disenchantment and Re-Enchantment in Malaysia's Uplands*. Singapore: NUS Press, 2014.
49 Robarchek CA. Blood, thunder, and the mockery of anthropology: Derek Freeman and the Semang thunder-god. *J Anthropol Res* 1987;43:273–300.
50 Goldberg TL, Blevins E, Leis EM et al. Plasticity, paralogy, and pseudogenization: rhabdoviruses of freshwater mussels elucidate mechanisms of viral genome diversification and the evolution of the finfish-infecting rhabdoviral genera. *J Virol* 2023;97:e00196–23.
51 Benko M, Aoki K, Arnberg N et al. ICTV virus taxonomy profile: Adenoviridae 2022. *J Gen Virol* 2022;103:001721.
52 Bhatia ML, Bora SS. Bionomics and distribution of the land leeches of the Kumaon Hills. *J Bombay Nat Hist Soc* 1973;70:36–56.
53 Hildebrandt JP, Lemke S. Small bite, large impact–saliva and salivary molecules in the medicinal leech, *Hirudo medicinalis*. *Naturwissenschaften* 2011;98:995–1008.
54 Joslin J, Biondich A, Walker K et al. A comprehensive review of hirudiniasis: from historic uses of leeches to modern treatments of their bites. *Wilderness Environ Med* 2017;28: 355–61.
55 Needham R. Blood, thunder, and mockery of animals. *Sociologus* 1964;14:136–49.
56 Sumabila A, Lugo MR. An emic approach, representation and clasification of mosquitoes among the cuiva people. *Antropológica* 2007;107–108:71–88.
57 Flamand C, Fritzell C, Obale P et al. The role of risk proximity in the beliefs and behaviors related to mosquito-borne diseases: the case of chikungunya in French Guiana. *Am J Trop Med Hyg* 2017;97:344–55.
58 Inhorn MC, Brown PJ. The Anthropology of Infectious Disease. In: *The Anthropology of Infectious Disease*. London: Routledge, 1997.
59 McGrath JW. Biological impact of social disruption resulting from epidemic disease. *Amer J Phys Anthropol* 1991;84: 407–19.
60 Hewlett B, Hewlett B. *Ebola, Culture and Politics: the Anthropology of an Emerging Disease*. Belmont: Thomson Wadsworth, 2007.
61 Douglas M. *Purity and Danger: an Analysis of Concepts of Pollution and Taboo*. London: Routledge, 2003.
62 Hinchliffe S. More than one world, more than one health: re-configuring interspecies health. *Soc Sci Med* 2015;129: 28–35.
63 Duda R, Betoulet JM, Besombes C et al. A time of decline: an eco-anthropological and ethnohistorical investigation of mpox in the Central African Republic. *PLOS Global Public Health* 2024;4:e0002937.
64 Giles-Vernick T, Owona-Ntsama J, Landier J et al. The puzzle of Buruli ulcer transmission, ethno-ecological history and the end of "love" in the Akonolinga district, Cameroon. *Soc Sci Med* 2015;129:20–7.

Received: 12 September 2025. **Revised:** 13 April 2026. **Accepted:** 12 June 2026