Heat events and Australian flying-foxes

Fact Sheet

April 2025

Key points

- Heat stress is the most common cause of mass mortality in Australian flying-foxes. Flying-foxes have experienced mass mortality events in the tens of thousands due to heat stress.
- Heat stress (also termed heat-induced illness) occurs when normal thermoregulatory behaviours are no longer sufficient to maintain a healthy body temperature, resulting in heat-induced illness which can lead to fatal hyperthermia.
- Mass mortality events due to heat stress have been reported in grey-headed, black, and spectacled flying-foxes in Australia.
- Heat-related mass mortality events have the potential for significant population impact, with one such event resulting in over 20,000 deaths of spectacled flying-foxes, an endangered species.
- Heat-related mass mortality events have become more frequent over recent decades and, with climate change continuing to increase the incidence and severity of heat events, this trend is expected to continue.

Species affected and aetiology

Flying-foxes (genus *Pteropus*) are frugivorous/nectivorous megachiropteran bats. Four flying-fox species inhabit mainland Australia, the grey-headed flying-fox (*Pteropus poliocephalus*), spectacled flying-fox (*P. conspicillatus*), black flying-fox (*P. alecto*) and little red flying-fox (*P. scapulatus*). Mass mortality events (MMEs) have been confirmed in grey-headed, spectacled and black flying-foxes [1]. The little red flying-fox displays the greatest heat tolerance of the four mainland species, likely because it inhabits arid, inland regions where extreme heat is frequent [2].

In response to heat, flying-foxes will display normal thermoregulatory behaviours. Heat stress occurs when these normal thermoregulatory behaviours are no longer sufficient to maintain a healthy body temperature, at which stage signs of heat-induced illness (heat stroke) are displayed (see *Clinical signs*). Heat stroke can progress to fatal hyperthermia.

One Health implications

Wildlife and the environment

Several flying-fox species have experienced catastrophic losses due to heat stress, with mortalities in the tens of thousands [1-3]. The loss of many individuals from a population at one time will impact group dynamics and may threaten species conservation [4]. Heat stress may compound other existing threats to species conversation, as the spectacled flying-fox is listed under the IUCN Red

List and EPBC Act as Endangered, and the grey-headed flying-fox as Vulnerable [5-9]. In 2018 in Cairns, over 20,000 individuals of the endangered spectacled flying-fox were estimated to have died in a single heat stress event [10, 11]. Decline in flying-fox numbers also impacts the integrity of Australia's forest ecosystems, as flying-foxes are important for long-distance pollination and seed dispersal [12]. The removal of large numbers of flying-foxes from the environment may result in the altered distribution range and status of multiple plant species, with further possible flow-on effects for healthy, functioning ecosystems.

Humans and domestic animals

Humans and domestic animals may be exposed to large numbers of sick flying-foxes and flying-fox carcasses following extreme heat events. This can result in risks to public and domestic animal health, considering that bats are natural hosts for a range of zoonotic diseases, particularly Australian bat lyssavirus [13]. Humans and other species may also be negatively affected by high ambient temperatures. Events involving many sick, dying and dead animals may have negative impacts on the mental health of wildlife rehabilitators. The high influx of heat stressed and orphaned flying-foxes coming into care following heat events has the potential to overwhelm the capacity of wildlife rehabilitators.

Occurrences in Australia and globally

Heat stress, leading to heat stroke, is the most common cause of MMEs in Australian flying-foxes. Extreme heat-related mass mortality events in flying-foxes have occurred in Australia for decades and are becoming more frequent [2]. Because of climate change, this trend is to expected to continue, and MMEs of greater magnitude can be expected to occur [3].

The summer of 2013-14 recorded over 50,000 deaths, mainly black flying-foxes [1, 14]. The 2018-19 summer saw over 48,000 heat-related flying-fox deaths, including approximately 23,000 spectacled flying-foxes, 20,000 black flying-foxes, 4,000 grey-headed flying-foxes and another 1,000 in smaller die-offs [1].

During the 2019-20 summer period (where conditions both contributed to, and then were exacerbated by, the "Black Summer" bushfires), eight discrete extreme heat events resulted in MMEs at 40 flying-fox camps across NSW, Vic, SA and the ACT. A cumulative loss of over 72,000 individuals, with a further 2,612 juveniles dying from pup abandonments, is a conservative estimate. These numbers do not account for additional deaths associated with the environmental conditions at the time, such as nutritional stress from resource loss or direct injury from bushfire [1].

Pteropodid bat MMEs associated with heatwaves have also been recorded in South Asia and Africa [15, 16].

Epidemiology

Flying-foxes have a narrow optimal daytime body temperature range and, like all mammals, have a limited ability to dissipate heat through evaporative cooling techniques and other thermoregulatory behaviours. Extreme heat-related MMEs generally take place over the summer months when ambient temperatures become so high that the animal's thermoregulatory capacity is overwhelmed, resulting in fatal hyperthermia [17]. Rapid, large-scale deaths are observed in Australian flying-foxes even with relatively short exposures to extreme heatwaves, likely due to direct heat stress injury combined with dehydration due to evaporative water loss from the skin and respiratory surfaces. A study in south-east Qld evaluated the use of forecast air temperatures to predict flying-fox mortalities and suggested 42°C as the air temperature threshold for flying-fox mortality in that region, while noting the importance of other environmental factors such as humidity and wind speed, and animal factors such as fur depth and body mass [3]. The 'critical temperature' at which heat-related illness occurs is likely to differ depending on ambient environmental conditions.

The rise in the occurrence of MMEs in recent years most likely correlates with the increasing frequency of heatwaves as a result of anthropogenic climate change. Flying-foxes are increasingly inhabiting urbanised areas [18-20], further exacerbating their exposure to high temperatures due to the urban "heat island" effect [21]. The environmental conditions that cause heat stress events can also cause MMEs through other mechanisms. High temperatures, along with drought conditions and bushfires, are drivers of food scarcity and starvation for flying-foxes, which can result in MMEs that tend to occur over longer periods than seen with heat stress events.

Black flying-foxes appear to be more susceptible to heat stress than grey-headed flying-foxes [22] and their range is shifting south [2, 23], where they will encounter greater extremes in ambient temperature, thus increasing the risk of MMEs [24]. Adult females and juveniles experience higher mortality rates relative to adult males in both black and grey-headed flying-foxes [2]. Flying-foxes rear their young during the hottest months of the year; pups are typically born between October-November and stay with their mothers until weaning in February-March [25]. It is possible that it is harder for mothers to maintain safe body temperatures during a heatwave due to the increased thermal load of carrying their pups on their chests during their first month, as well as the elevation of basal metabolic rates, thermoregulatory requirements and energetic costs during lactation [2]. Death of mothers results in the death of their dependant pups. Abandonment and subsequent death of pre-weaned pups can occur even when temperatures do not reach the critical threshold, due to the stress experienced by flying-fox mothers [1]. Flying-foxes with deeper fur may be more susceptible to heat stress as the fur limits heat dissipation [26].

Clinical signs

In response to increased ambient temperatures, flying-foxes start by displaying normal thermoregulatory behaviours including wing-fanning to aid convection; panting and saliva-spreading to promote cooling via evaporation; moving lower in the canopy and seeking out cooler microclimates on tree trunks. Once the critical temperature is crossed, these behaviours may become insufficient, and individuals start to cluster on trees, often descending the tree, become weakened, dehydrated, lethargic, comatose and end up on the ground. Fatal hyperthermia can occur within 20 minutes [2]. Animals with heat-induced illness will record rectal temperatures at or above 40°C [27].

Diagnosis

Flying-fox MMEs involving individuals across age and sex demographics are typically attributed to hyperthermia without the need for laboratory diagnosis, as they occur during extreme heat events [1]. If the recorded ambient temperature on the day of an MMEs reaches or exceeds the critical temperature, a diagnosis of fatal hyperthermia can be assumed. Heat stress should be considered as a differential diagnosis at lower temperatures as mortalities may occur due to the interplay with other environmental and animal related factors, which are not fully understood.

Pathology

Pathological changes have not been described in Australian flying-foxes following mass mortality events, due to the absence of laboratory diagnosis and necropsy data. Investigation of non-pteropodid bats involved in a heat-induced MMEs in Cambodia revealed localised, mild haemorrhage of the lungs, liver and spleen [28].

Treatment

There are state-specific guidelines for intervention in flying-fox heat-related events:

- NSW https://www2.environment.nsw.gov.au/topics/animals-and-plants/wildlife-management/management-flying-foxes/heat-stress-in-flying-fox-camps/responding-to-heat-stress
- Qld https://www.qld.gov.au/environment/plants-animals/animals/living-with/bats/flying-foxes/about-flying-foxes/flying-fox-mass-dying-events-and-heat-stress-events
- Vic https://www.wildlife.vic.gov.au/wildlife-emergencies/heat-stress-in-wildlife

The following treatment and intervention methods for reducing hyperthermia in wild flying-fox populations are supported by observations made by experienced wildlife rehabilitators and veterinarians [27]. However, there are no reports of controlled studies to measure relative effectiveness of different methods, and there is ongoing research occurring in this area [27].

Camp-scale interventions

- **Manual spraying of roost vegetation:** dampening and cooling camps without directly spraying flying-foxes, instead directing the spray above flying-foxes and allowing water to fall downwards onto them using the prevailing air movements to obtain maximum coverage. Animals can hydrate by licking water droplets off their fur and vegetation. Serious concerns exist regarding the potential disturbance of roosting flying-foxes, causing increased thermal exposure, and the risk of elevating humidity (which may exacerbate heat stress). Spraying is not recommended in certain conditions or camp environments e.g. enclosed camps in more humid environments. Wildlife carers should be on hand to tend to animals that are overwhelmed. Directly spraying water at or near individuals, with even moderate pressure, is **not** recommended due to the potential to cause further stress and force already exhausted bats to take flight. There is also a risk of hypothermia due to water interventions.
- **Ground-based sprinklers:** many such sprinklers already exist in urban greenspaces inhabited by flying-fox colonies. Activating sprinklers during heatwaves provides some cooling, although

there are concerns regarding humidity (see above). Ground-based sprinklers may be most effective in conjunction with manual spraying and the presence of carers to tend to animals that have collapsed.

- **Canopy-mounted sprinkler systems:** pre-installed sprinkler systems mounted within the camp canopy. This intervention method has only been trialled a handful of times but has seen anecdotal success. Activation of the system and scaling the response should be based on observation of flying-fox behaviour in the camp, to avoid the risk of over-use of sprinklers.
- **Artificial wind, shade and cooling:** conceptually, this could minimise energetic costs to individuals by reducing the need for wing-fanning and improve evaporative cooling, especially in conditions of high humidity. However, there is the potential to exacerbate dehydration and to cause noise disturbance. These methods have not yet been implemented in flying-fox camps.

Treatment of individuals

Only rabies-vaccinated people who are experienced in handling bats and are wearing appropriate personal protective equipment (PPE) should handle, rescue or examine a bat. Only licensed wildlife rescue and rehabilitation providers or veterinary personnel should handle flying-foxes.

Flying-foxes should only be removed from a roost if immediate veterinary attention is warranted and available. Retrieving individual flying-foxes can lead to disturbance and increased stress for the other flying-foxes in the camp.

There are many techniques for treating individual flying-foxes suffering from heat-induced illness. The appropriate approach will vary with circumstance. A comprehensive review of the following treatments is provided by Mo and Roache 2020 [27]. Further study is required to develop a standardised treatment plan.

- **Cooling with tepid or room temperature water (immediate triage preceding rehydration):** gentle hand-spraying, particularly on the wings (when used *in-situ*, only for individuals already on or near the ground) or slow immersion in water. When employing cooling measures on severely affected bats removed for treatment, it is important to monitor the animal's rectal temperature to ensure it does not fall below the optimal range (37-39°C) e.g. stop active cooling at 40°C and monitor.
- **Rehydration:** subcutaneous or intravenous fluid rehydration, eye drop application, glucose on gums (if it can be safely applied) or added to fluids. Severely affected animals will be dehydrated and/or in shock and will therefore not be able to absorb oral fluids and there is a risk of aspiration, leading to pneumonia. Debilitated animals should not be force-fed fluids or food.
- **Chemical intervention:** sedation is an option to assist handling and treat myopathy.

Euthanasia may be required in cases where individuals are severely compromised or treatment is unsuccessful. Thresholds for euthanasia have not been consistently outlined in the literature and the advice of an experienced wildlife veterinarian should be sought [27].

Prevention and control

With projected increasing frequency of high temperature days, efforts to prevent Australian flying-fox mass mortality events should focus on intervention to minimise heat-induced illness in wild populations. Temperature forecasts should be closely monitored, coupled with the expected time of the peak, humidity and wind, especially in summer, to prepare for days when MMEs are likely. Ideally, camp-specific response plans will be developed, including a set of triggers for monitoring, activation and deactivation of response activities, based on flying-fox behaviour and ambient temperature and humidity. Population data should be up to date so that intervention and rehabilitation can focus on these areas if necessary. Camps should be actively monitored on days when the ambient temperature is expected to reach or exceed the critical temperature, while being careful to avoid disturbance of the flying-foxes (thereby adding to the stress of the animals present). Western Sydney University and The University of Melbourne have developed a *Flying-Fox Heat Stress Forecaster* (https://www.animalecologylab.org/ff-heat-stress-forecaster.html) that uses weather data from the Bureau of Meteorology and flying-fox roost data from the National Flying-fox Monitoring Program to predict roost locations at risk of heat stress events, up to three days in advance.

The use of data loggers and remote video cameras also allows for remote roost monitoring. Well-positioned data loggers installed in camps provide accurate temperature and humidity readings within a roost while cameras allow flying-fox behaviour to be monitored remotely by responders who can then make further decisions regarding a potential heat event response [29].

The roost vegetation structure will influence the temperature and humidity that flying foxes are exposed to and roost site enhancement should be considered in preventative processes. Creating a roost vegetation structure including a canopy, mid-storey and understorey provides shade, refuge and enhances different microclimates during heat stress events [29]. Other preventative measures include installing sprinklers near at-risk colonies (see *Treatment* for considerations). Camp response plans should identify if and where sprinklers are installed so they may be activated during a heat event [30].

Public education regarding both the importance of flying-foxes in Australia and the threats they face should be a priority. Bats are often maligned and misunderstood animals and flying-foxes that roost near residential areas are often deliberately disturbed or injured, being perceived as a dangerous nuisance [31]. These human-wildlife conflicts are extremely stressful, especially to animals already suffering heat stress, and amending public perception will be necessary to reduce risks.

In the event that MMEs do occur, they should be reported immediately, and carcasses should be removed as quickly as possible to minimise risks to biosafety, especially from areas shared by humans or livestock,.

Research

Further research into the following areas will assist in understanding of heat-related flying-fox mass mortality events in Australia and how best to manage and prevent them in the future:

- What management responses and intervention methods can prevent heat stress deaths and help lessen the impacts of these events on flying-fox individuals, camps and populations? Do these change with species, age, location and other factors?
- What are the most effective preventative strategies for at-risk flying-fox camps?
- What are the ecophysiological drivers of vulnerability of Australian flying-fox species to extreme heat events?
- What are the implications of extreme heat events for flying-fox (and other wildlife) populations?
- Nationally coordinated monitoring of flying-fox populations for baseline data and to determine changes in distribution and abundance.

Surveillance and management

Government flying-fox surveillance is informed by monitoring methodology developed by the CSIRO [32]. From 2013 to 2022, the National Flying-Fox Monitoring Program was a collaborative project between the Australian, NSW, Qld, Vic, SA and ACT governments and CSIRO Land and Water to monitor flying-fox distribution and abundance. Quarterly counts of daytime roost sites of grey-headed and spectacled flying-foxes were recorded, as well as black and little red flying-foxes when they occurred within the range of the first two species. This census data to 2022 is presented in an interactive web viewer (www.dcceew.gov.au/environment/biodiversity/threatened/species/flying-fox-monitoring). The *Australian Flying-fox Monitor* (https://www.flyingfoxes.info) maps population monitoring data for Australian flying-fox species. The *Flying-Fox Heat Stress Forecaster* helps to identify flying-fox roosts that may be at risk [3] (www.animalecologylab.org/ff-heat-stress-forecaster.html).

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.

Extreme heat events can be reported to the University of Western Sydney Lab of Animal Ecology: https://www.animalecologylab.org/heat-stress-data-form.html. MMEs in flying-foxes due to other causes can be reported to WHA: https://wildlifehealthaustralia.com.au/Resource-Centre/Bat-Health#Flying-fox%20Mass%20Mortality%20&%20Morbidity%20Events.

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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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