Science for Saving Species

Research findings factsheet

Project 4.4.3.1

Threatened Species Recovery Hub

National Environmental Science Programme

Predicting heat stress of flying-foxes using a biophysical model

In brief

Extreme heat events are becoming more frequent, prolonged and intense, yet our ability to predict the time, place and magnitude of their impacts on threatened wildlife is limited. Australian flying-foxes are prone to mass heat-stress die-offs, with some recent die-offs at extreme scales of over 45,000 individuals in a single event.

We developed a physiological model to increase the accuracy of predictions about which flying-fox roosts were most at risk of die-offs compared to previous methods. The model uses not only ambient air temperature but also other meteorological factors such as relative humidity, radiation and wind speed plus physiological factors such as fur properties and behaviours like panting, licking and fanning. Testing in the laboratory and field found that the model accurately and precisely captured the behavioural and physiological responses of flying-foxes.

The research will be used to extend a "Flying-fox Heat Stress Forecaster" to help those involved in managing flying-fox camps during extreme heat events. The forecaster predicts which flying-fox camps are most likely to be exposed to extreme heat up to 72 hours into the future on the basis of an air temperature threshold. It can help managers and policy-makers allocate scarce resources towards the most at-risk roosts. The biophysical model provides a more detailed perspective on heat stress and allows managers and policy-makers to decide on the most effective short-term management strategies such as spraying and long-term ones such as habitat manipulation.

Black headed flying fox (Pteropus alecto). Image: Andrew Mercer, CC BY-SA 4.0 Wikimedia Commons

Background

The magnitude, frequency and duration of extreme heatwaves is increasing due to anthropogenic climate change, with Australia having experienced nine of its 10 hottest years on record since 2005. However, we have limited ability to predict how these heatwaves may affect animals, in terms of time, place and magnitude of impacts.

Australian flying-foxes (*Pteropus* spp.) are large bats that form daytime roosts (known as "camps") among the exposed branches of canopy trees that can comprise tens of thousands of individuals. These roosts may be located in mangroves, swamps and rainforest, often close to water and, increasingly, in urban locations. Flying-foxes in Australia are already affected by extreme heatwaves, with thousands of them dying in single-day events. While records of such die-offs date back to European arrival, more systematic recordings since the late twentieth century have been at extreme scales. In January 2014, it is estimated that 45,500 flying-foxes of two species died in 52 camps during an extreme heat stress event in south-east

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Background (continued)

Queensland, the largest flying-fox die-off event ever recorded.

Flying-fox heat stress is complex, and involves not just ambient air temperature, but also solar radiation, long-wave radiation, wind speed and humidity and the interactions of these factors with the behaviour and physiology of the flying-fox. Positive feedbacks from panting, increasing core temperatures and fanning are involved, which all increase the flying-fox metabolic rate and hence the heat load. Evaporative cooling, from water evaporating from the skin or fur, is a potent means of heat loss, as long as the atmospheric humidity is sufficiently low; however, when the air is saturated with moisture, an animal's ability to lose heat through evaporative cooling can be constrained.

The grey-headed flying-fox (*Pteropus poliocephalus*), Australia's largest flying-fox, is listed nationally as Vulnerable. The species feeds on fruit and nectar and plays an important ecosystem role in pollination and seed dispersal for a wide range of native trees. While the species occurs along the coastal belt from Rockhampton in central Queensland to Melbourne, it uses only a small proportion of its range at any one time, as it selectively forages and roosts depending on the availability of food. It is prone to heat-related deaths, and 5000 to 7000 individuals were recorded to have died during a heatwave in 2004 when ambient temperatures reached 45°C.

In November 2018, there was a heat stress–related die-off of approximately 23,000 spectacled flying-foxes (*Pteropus conspicillatus*), a species that is listed as Endangered by the EPBC Act and had previously not been affected by extreme heatwaves. This single-event die-off wiped out almost third of the entire population of just 75,000.

Black flying-foxes (*Pteropus alecto*) are common in northern Australian (as well as Papua New Guinea and Indonesia) and are not listed nationally, although they face threats such as loss of foraging and roosting habitat and extreme temperature events.

The extreme mortality of heat-related die-offs places the stability of flying-fox populations at risk and threatens the key pollination and seed dispersal services afforded by these species. It also places enormous demands on wildlife management and conservation agencies and raises important concerns for human health due to bats being vectors for lyssavirus and Hendra virus. Managers and agencies have an urgent need for ways to accurately predict when and where die-offs are likely to happen, so that they can respond most effectively to these events.

Research aims

We looked at ways of making stronger predictions about the risk of heat-stress die-off of flying-foxes than are available through simple measurement of air temperature. We aimed to increase the accuracy of predicting flying-fox die-offs due to heat stress through using a biophysical model. This method would not only account for air temperature but also for other factors that affect the heat budget of the flying-fox, such as relative humidity, wind speed, fur properties and physiological responses like panting, licking and fanning.

Spectacled flying fox (Pteropus conspicillatus)*.*
Image: Justin Welbergen, CC BY 3.0 Wikimedia Commons

What we did

Our work took place between 2015 and 2020, with data collection at the University of Western Sydney and model design and testing at The University of Melbourne.

We took a 2008 study that concluded that flying-fox die-offs are associated with ambient air temperatures higher than 42°C, and evaluated the accuracy of using the 42°C threshold by gridding hourly forecast air temperature to predict flying-fox die-offs.

To improve these predictions of heat stress and understand how different factors affect flying-fox heat budgets, we modified the generic endotherm (i.e., heat produced by bodily functions) model of the biophysical modelling package "NicheMapR" for grey-headed, black and spectacled flying-foxes.

We either sourced values for the different parameters of the endotherm model from published studies or measured them ourselves. Our measurements included a range of properties of fur and wings from specimens sourced at the Melbourne Museum and Australian Museum.

We determined a sequence of behavioural and physiological responses to heat stress conditions, assembled using information from field observations and published literature. Weather data (air temperature, relative humidity and wind speed) from occasions of past flying-fox die-offs were extracted from published studies, the Bureau of Meteorology Climate Data Online public database, the Australian Water Availability Project database and the daily wind database.

We tested the model against laboratory and field data. We collated data on grey-headed flying-fox die-offs and corresponding weather across Australia in 2014 and used these data to evaluate whether the biophysical model is better at forecasting die-offs and identifying refuges than using an air temperature threshold.

Finally, we used the model to produce an advisory document on heat stress in flying-foxes for the Queensland Government.

Key findings

The tailored model we developed was found to accurately and precisely capture the behavioural and physiological responses of flying-foxes in the laboratory and in the field. These responses include changes in core body temperature, metabolic heat generation, panting and fanning. We were able to incorporate the complexities of the last of these factors, wing fanning, which can assist in cooling but becomes a liability under solar radiation due to the increased surface area for solar heat gain. It is also problematic as it has the effect of generating metabolic heat.

Heat stress in flying-foxes can rapidly escalate and care is required to ensure any management to reduce heat stress in these species does not cause excessive metabolic heat production or high local humidity levels.

The success of predictions made using the 42°C threshold model was high, although we concluded that there was room for this model to be improved to ensure that it captured a greater proportion of potential heat die-offs.

Based on the forecaster model that we tested here, we developed the "Flying-fox Heat Stress Forecaster" and associated website (http://www.animalecologylab.org/ff-heat-stress-forecaster.html) to help those involved in managing flying-fox camps during extreme heat events. Before our model, predictions were made manually using publicly available resources, which led to accuracy issues due to the lag times for weather updates.

The forecaster incorporates information on flying-fox camp locations and occupancy obtained from the National Flying-Fox Monitoring Program and obtains the latest available ACCESS-G air temperature forecast from the NCI Data Collections archive every six hours. The forecaster provides a daily list of flying-fox camps exposed to heat stress (air temperatures above 38°C threshold) and where mortality is likely (42°C threshold). It also provides temperature profiles of the camps where heat stress is likely to be worst. It can predict which flying-fox camps are most likely to be exposed to extreme heat up to 72 hours into the future.

The forecaster will be of greatest utility to flying-fox colony managers and policy-makers, as an early

Key findings (continued)

warning system to increase preparedness for die-offs under future climate change scenarios.

The Flying-Fox Heat Stress Forecaster website went live in time for a heat stress event in February 2017 and was valuable to many stakeholders in South Australia and New South Wales in allocating their limited resources efficiently towards camps that were likely to be worst affected by that event. Subscribers include government officials, wildlife rehabilitators, human healthcare professionals and consultants.

Further research on flying-fox heat stress is required to enable predictions that are more species-specific and habitat-specific. This will require more detailed measurements of the physiological and behavioural traits of flying-fox ecology and habitat features identified by the biophysical model (e.g., Ratnayake et al. 2021). More work is also needed to assess the effects of administering water to flying-foxes, especially how it affects their activity level (and associated heat production) in different levels of ambient humidity. This further work could be combined with our modelling work to develop specific advice on the best way to manage flying foxes according to specific weather conditions (e.g., spraying with water) and flying fox life history (e.g., breeding vs. non-breeding).

Overall, analyses and empirical studies such as ours will produce a clearer framework for deciding on short-term management strategies such as spraying camps with water to cool flying-foxes and long-term ones such as habitat manipulation.

Models like ours could also be used for any species for which thermal tolerance data exists. Use of such tools therefore promises to help prioritise management actions aimed at conserving biodiversity in the face of climate change.

Cited material

Ratnayake, Himali Udeshinie 2018. Understanding how extreme heat events affect the heat budgets of Australian flying-foxes (*Pteropus* spp.): Roles of morphology, physiology and behaviour. PhD thesis, The University of Melbourne.

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Grey headed flying fox (Pteropus poliocephalus). Image: Andrew Mercer, CC BY-SA 4.0 Wikimedia Commons

Further Information

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