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Mass mortalities of grey-headed flying-foxes (*Pteropus poliocephalus*) from tree collapses

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ABSTRACT

Mortality factors are an important subject of research, especially when mortalities concern threatened taxa. The grey-headed flying-fox (*Pteropus poliocephalus*) is a vulnerable species endemic to eastern and south-eastern Australia that is known to be susceptible to a spectrum of compounding threats including factors producing simultaneous deaths. We describe two incidents of trees within a flying-fox roost collapsing and causing mass mortalities in individuals roosting in those trees. Each incident resulted in 335 and 57 deaths, as well as 74 and 45 individuals that would have died if not taken into *ex-situ* care. Total mortality for each incident equated to approximately 15% and 2% of the colony at the time of those incidents. Although flying-foxes are capable of flight, take-off from a roosting position requires an initial freefall, which makes escape from a collapsing tree difficult. Our accounts potentially represent the first reports of tree collapses causing mortality in Australian flying-foxes, which highlight the relevance of tree health in roosts to flying-fox welfare and conservation. This information also builds upon our growing knowledge of factors producing mass mortalities in flying-foxes.

Keywords: Australia, bats, flying-fox roost, mortality factors, New South Wales, Pteropodidae, threatened species, vulnerable species, wildlife mortality.

Introduction

There are growing concerns for the conservation of flying-foxes (genus *Pteropus*). Of the 65 species evaluated by the International Union for Conservation of Nature (IUCN), 38 are currently considered threatened and 6 species are already considered extinct (IUCN 2024). As a result, causes of flying-fox mortality have garnered substantial scientific interest (Tidemann and Nelson 2011; Vincenot *et al.* 2015), particularly in factors that produce mass mortality events (Welbergen *et al.* 2008; Ratnayake *et al.* 2019; Mo *et al.* 2022*a*). Notably, flying-foxes roost in colonies that can at times contain hundreds of thousands of individuals (Eby 1995; Hall 2002; Mo *et al.* 2020). As a result, factors that affect roost sites have impacts on several individuals simultaneously, and mortalities of hundreds or thousands of individuals have been recorded in some events (Welbergen 2012; O'Shea *et al.* 2016).

The grey-headed flying-fox (*Pteropus poliocephalus*) is endemic to the temperate and subtropical regions of eastern and south-eastern Australia. Under New South Wales (NSW) environmental legislation, the species is listed as vulnerable to extinction (NSW Scientific Committee 2001), based on evidence of a population decline of at least 30% between surveys in 1989 (Parry-Jones 2000) and 1998 (Eby *et al.* 1999), as well as the substantial removal of critical winter foraging habitats in the coastal regions of south-eastern Queensland and north-eastern NSW (Eby 1995). The grey-headed flying-fox has also been assessed as a Vulnerable species under the IUCN (Eby *et al.* 2021) and Australian federal legislation (Commonwealth of Australia 2015). The latter has prompted a national recovery plan for the species (Department of Agriculture, Water and the Environment 2021), which highlights the broad spectrum of compounding threats to the species (Mo *et al.* 2023*a*), including factors producing mass mortalities such as extreme heat events (Welbergen *et al.* 2008) and food shortages (Ratcliffe 1931; Eby *et al.* 2023).

Here, we report observations of two instances of a previously undocumented source of mass mortalities in the grey-headed flying-fox, simultaneous deaths and injuries from tree collapses within a roosting site.

Observations

Both mortality events were observed in a flying-fox roost situated within a 37-ha golf course in the western portion of the township of Cowra, NSW, Australia (33.8408°S, 148.6806°E). The eastern perimeter of the golf course runs parallel to the Lachlan River, with a separation of 140–240 m at different points. Roost vegetation provided by the golf course comprises sparsely scattered trees. The roost is seasonally occupied, with a colony typically present during the warmer months of the year and vacating during the cooler months (NSW DCCEEW, unpubl. data). During periods of occupancy, grey-headed flying-foxes are the primary species present, with little red flying-foxes (*Pteropus scapulatus*) less frequently present. Counts of the number of flying-foxes present at any one time range from less than 100 individuals to up to 30,000 individuals (NSW DCCEEW, unpubl. data). The area that the colony covers varies depending on the size of the colony but is typically no more than 8 ha. At times, larger colony sizes have coincided with the colony expanding beyond the boundaries of the golf course and into roost vegetation along the Lachlan River.

The first mortality event occurred on 19 August 2018 at approximately 15:00 hours. Maximum wind gusts of 83 km per hour were recorded at the Cowra Airport automatic weather station (Australian Bureau of Meteorology 2018), approximately 2.5 km from the roost. This caused a large section of a pine tree (*Pinus* sp.) to break off its main trunk and collapse (Fig. 1). Observers were immediately alerted from the commotion. Mortalities of 335 grey-headed flying-foxes were recorded, including 37 individuals that were subsequently euthanised due to their injuries.[1] Some carcasses were found metres from where the section of tree landed, potentially hurled to those locations during the collapse or as a result of injured individuals crawling away to reach other trees before dying. On the day of impact, there were approximately 2800 grey-headed flying-foxes in the roost, determined through direct counts of all individuals, and no little red flying-foxes present. Hence, the deaths represented 12% of the colony. There were also 74 injured flying-foxes that were rescued and taken into *ex-situ* care by wildlife rehabilitators, many of which were pregnant females. Assuming that these individuals would have likely also died were it not for intervention, the total mortality from this incident would have totalled approximately 409 flying-foxes, equating to mortality closer to 15% of the colony.

Carcasses of the 335 dead individuals were collected, frozen, and shipped to Griffith University, Nathan, Queensland, for examination (Queensland Department of Environment and Science Wildlife Movement Permit #WA0009322). Veterinary examinations by one of the authors (AJP) showed that all individuals had sustained injuries that were consistent with death as a result of trauma, such as crushed abdomens, crushed thoraxes, broken leg, wing and jaw bones, and blood from the nose. While a lightning strike cannot be ruled out, there was no direct evidence of lightning strike on the tree or surrounding grass, such as burns, or in the carcasses, such as singe marks.

Demographic (species, age class, sex, reproductive status) and morphometric measurements (forearm length, tibia length, body mass) were recorded for all 335 individuals (Table 1). Age categories were assigned using a combination of sexually dimorphic ranges (juveniles, smaller than adult body size [generally <150 mm forearm and <450 g mass], not sexually mature, assumed to be <12 months of age; sub-adults near or at adult body size, not sexually mature, assumed to be 12–24 months; adults, full body size [generally >160 mm forearm and <550 g mass], with females showing evidence of prior lactation [elongated nipples] and males with enlarged penis and descended, enlarged testes, assumed to be >24 months). Half of the individuals killed were adults (50%), one-third were juveniles (33%), and the remainder were sub-adults (17%). However, it is unknown whether this is representative of the age structure of the colony as a whole.

The pregnancy status of adult females was assessed based on dissection, revealing that 95 of the 100 adult females that died were pregnant. These dissections also showed trauma to internal organs, further supporting physical trauma as the cause of death. Foetuses removed from these 95 adult females were sexed, weighed, measured and retained for foetal development studies. Wing membrane punches, hair, canine and premolar teeth, and blood samples were collected for future research applications.

The second mortality event occurred on 21 November 2022. An entire pine tree containing grey-headed flying-foxes collapsed, with the commotion prompting observers to be immediately alerted (Fig. 2). On this day, Cowra had experienced maximum wind gusts of 69 km per hour and there had been flooding on the golf course from 80.2 mm of rainfall on 14 November 2022 (1 week prior to the mortality event) (Australian Bureau of Meteorology 2022). Mortalities of 57 individuals were recorded, including 9 individuals that were euthanised at the site due to their injuries. On the day of impact, approximately 4400 grey-headed flying-foxes were counted in the roost and no little red flying-foxes were present. Hence, these deaths represented 1% of the colony. There were 45 injured flying-foxes rescued and taken into *ex-situ* care. If these animals were included in the total

[1]Wildlife carers and veterinarians attended the incident. Euthanasia was performed by veterinarians.

Fig. 1. Dead grey-headed flying-foxes visible next to the tree that collapsed in the August 2018 incident. Photographs, Gerardine Hawkins.

Table 1. Demographic summary of grey-headed flying-foxes killed in the August 2018 incident.

Age class	Birth cohort	Sex		Totals per age class
		Female	Male	
Juvenile	2017–2018	72 (21%)	40 (12%)	112 (33%)
Sub-adult	2016–2017	16 (5%)	41 (12%)	57 (17%)
Adult	≤2016	100 (30%)	66 (20%)	166 (50%)

mortality, the mortality in this incident would have totalled 102 individuals, equating to 2% of the colony.

Discussion

Our existing knowledge of factors producing mass mortalities in Australian flying-foxes is largely centred around well-documented circumstances such as extreme heat events affecting roost sites (Welbergen *et al.* 2008, 2014; Mo *et al.* 2022*a*) and prolonged food shortages affecting extensive areas of foraging habitat (Ratcliffe 1931; Eby 1995; Eby *et al.* 2023), moderately documented circumstances such as bushfires (Mo *et al.* 2022*b*, 2024), and emerging circumstances as causes of mass paralysis (Buettner *et al.* 2013; Flying-fox Paralysis Syndrome Working Group 2022). The documentation of tree collapses as an additional cause of simultaneous deaths in flying-foxes builds upon this existing knowledge. To our best knowledge, there has only been one previous incident reported in scientific literature that has involved foliage-roosting bats as casualties from tree breakages (O'Shea *et al.* 2016). In that specific incident, 12 straw-coloured fruit bats (*Eidolon helvum*) were injured or killed in Uganda when a branch of a roost tree snapped off (Ogilvie and Ogilvie 1964). Our accounts involving the grey-headed flying-fox mirror that

Fig. 2. Dead grey-headed flying-foxes visible next to the tree that collapsed in the November 2022 incident. Note: in the top image, living flying-foxes were roosting in the branches even after the tree had collapsed. Photographs, Bel Manria.

report, although the recorded numbers of affected animals in both of the mortality events described here are substantially larger. Pertinently, mortalities associated with tree collapses are only likely to be known about in flying-fox roosts that receive a considerable amount of attention from interested persons, such as the example in this study of a roost situated on a golf course.

Unlike birds, bats lack the ability to split the wingtips into winglets that enables birds to increase lift (Lindhe Norberg *et al.* 2000), and so take-off from a roosting position requires an initial freefall. This makes escape from a collapsing tree difficult, especially if the tree collapse occurs at a faster speed than bats' freefall. In particular, members of the genus *Pteropus* also have comparatively high wing surface area and less manoeuvrability in flight than other pteropodid bats (Hall and Richards 2000), which may make them more susceptible to being implicated in tree collapses. Tree species and health likely play a role. Here, two separate events occurred in the same tree genus in a highly modified human landscape.

Tree health has traditionally been identified as an important consideration in flying-fox roost management from the perspective that trees vulnerable to collapsing and limb drops represent risks to human safety (Mo *et al.* 2023*b*). Current roost management practices make allowances for land managers seeking to remove weakened tree limbs and whole trees deemed to have the potential to fall on humans (Office of Environment and Heritage 2018). However. the observations reported here show that incidents where only a single tree collapses have the potential to inflict deaths and injuries in flying-foxes. Thus, hazards associated with weakened trees extend beyond matters of human safety and have potentially serious consequences for the welfare of flying-foxes in those roosts.

Finally, mass mortality events provide opportunity for obtaining biological data, samples, and insights from the affected species, which might otherwise be difficult or impossible to obtain. We can only speculate on whether the individuals killed in the first treefall represent an unbiased representation of the individuals present within a single roost tree just prior

to its collapse, given that age and sex structures can differ among trees within roosts (reviewed in Lunn *et al.* (2021)). However, the high observed pregnancy rate in adult females (95%), for example, aligns with existing observations (Eby *et al.* 1999, 2023). In wildlife emergencies, data such as those presented here are difficult to obtain because the response often relies on volunteers, whose primary focus is on rescuing viable individuals and alleviating suffering in those that cannot be saved.

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Data availability. The data that support this study can be shared upon reasonable request to the authors.

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