Department of
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Environment

Yarra Bend Park Flying-fox Campsite:

Review of the scientific Research

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Yarra Bend Park Flying-fox Campsite:
Review of the Scientific Research

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(Note that this document is based upon a scientific paper with complete references. For easier reading, citations have been removed and a list of sources is provided at the end of the document.)

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About this review

This Review is part of a set of three review papers addressing the effectiveness of the 2005 Yarra Bend Park Flying-fox Campsite Management Plan. The other two are:

- Yarra Bend Park Flying-fox Campsite: Review of the Management Plan
- Yarra Bend Park Flying-fox Campsite: Review of the Revegetation Plan

These three Reviews have been prepared for consultation purposes and to inform the development of a new Yarra Bend Park Flying-fox Campsite Management Plan.

Executive Summary

Since 2004, the Australian Research Centre for Urban Ecology (ARCUE) has been undertaking a research and monitoring program of the Grey-headed Flying-fox (GHFF) colony at the Yarra Bend Campsite.

The GHFF were relocated to Yarra Bend Park from the culturally and historically significant Royal Botanic Gardens Melbourne where they were causing serious damage to vegetation.

In 2005, the Department of Sustainability and Environment (DSE) developed a Flying-fox Campsite Management Plan for Yarra Bend Park to "provide a clear framework for managing Melbourne's flying-fox colony at Yarra Bend Park and creating a sustainable campsite".

ARCUE has conducted a review of the Flying-fox scientific research as part of the overall review of the Campsite Management Plan.

This is a summary of the research report prepared by ARCUE. It provides a snapshot of the results of the research conducted and makes conclusions and recommendations about potential future management activities.

This research work has been conducted in two broad research themes:

- Camp and population dynamics and
- Roost and camp conditions.

Camp and population dynamics

The number of flying-foxes within the camp varies seasonally and annually. The peak in summer/autumn is approximately 20,000–27,000 for static counts, and up to 30,000–35,000 for fly-out counts. The minimum population size is typically around 10,000 flying-foxes, but has been as low as approximately 5000 flying-foxes in mid-2007 and mid-2009.

Estimating reproductive output is an important element in understanding the demographic status of GHFF populations. The reproductive output results suggest that the Yarra Bend colony has a consistent annual birth rate, with approximately 85% of females each year giving birth and carrying young.

The number of males is also recorded in order to give an estimate of female to male sex ratio during the breeding season. Studies on sex ratio variations help to understand the social organisation and dispersal behaviour of GHFF. At Yarra Bend Park the average is 0.83 males to each female during the breeding season.

Since January 2006 there have been searches for dead flying-foxes within the Yarra Bend camp at fortnightly to monthly intervals and also following heat events. Flying-foxes are particularly sensitive to the effects of extreme temperatures, as they roost among the exposed branches of canopy trees. The extreme heat events in January and February 2009 caused a significant number of flying-foxes to die.

Roost and camp conditions

Dieback and defoliation of canopy trees used by roosting flying-foxes is a common occurrence at flying-fox campsites. Monitoring the health of roost trees is important for managing the campsite at Yarra Bend Park. It will assist in identifying which sections of the campsite may need to be restored.

To determine the rate of roost tree defoliation at Yarra Bend, on-site tree assessments have been carried out every 4–5 months since October 2006.

The results of the research suggest that flying-foxes are having an impact on roost trees, causing over 50% defoliation for some trees within sections of the campsite. In particular there is a lower percentage of leaf cover in areas that the flying-foxes occupy year-round.

A potential measure to reduce the impact of roosting flying-foxes on the vegetation is to provide artificial roosting structures. However, data on the roosting characteristics of flying-foxes at Yarra Bend Park suggest that if 20% of GHFF colony (5000 flying-foxes) required roosts this would equate to approximately 3.1 km of roosting space, which makes this option logistically impractical at Yarra Bend Park.

Climatic conditions play an important role in the dynamics of flying-fox camps. To explore the importance of microclimate of the camp sites, loggers were installed to record temperature and humidity at 15 minute intervals. There is now more than three years of data from

Background

Executive Summary continued

Yarra Bend, Geelong, Royal Botanic Gardens Melbourne (RBGM), and four camps in East Gippsland. The data is still being analysed, however, it is likely that an increase in understorey/mid-storey vegetation at Yarra Bend, plus efforts to restore the tree canopy, will be effective at reducing temperature and increasing humidity. The combination of temperature and humidity which may reduce or prevent heat-related mortality is not known at this stage.

Based on the scientific research data, the following management activities are proposed:

- Continue planting indigenous grasses and understorey plants.
- Plant more trees for future roosting opportunities, amongst existing roost trees as well as in sparse areas further up the Yarra River.
- More shrubs and small trees (particularly Silver Wattle) could be planted, especially in areas with little mid-storey on the golf course side of the Yarra River to provide more roosting opportunities/shelter during future heat events.

Ongoing research is important for understanding population dynamics and roosting requirements of GHFF at Yarra Bend Park.

Potential additional research which may assist in managing this GHFF camp has also been identified in this review.

Background and purpose of the review

In March 2003 the flying-foxes were dispersed from the Royal Botanic Gardens Melbourne (RBGM) as part of a strategic relocation program. A small proportion of the colony moved to Eastern Park in Geelong, and the remainder of the colony settled at Yarra Bend Park.

A Flying-fox Campsite Management Plan for Yarra Bend Park was prepared in 2005 to "provide a clear framework for managing Melbourne's flying-fox colony at Yarra Bend Park and creating a sustainable campsite".

Now, in 2009, the Campsite Management Plan is in the process of being renewed. To feed into the renewal process, three reviews have been prepared. These are:

1. Review of the Campsite Management Plan
2. Review of the Revegetation Plan
3. Review of the Scientific Research (this report).

The Review of the Campsite Management Plan looks specifically at the goals and actions outlined in the 2005 Flying-fox Campsite Management Plan and assesses the effectiveness of the actions. The Review of the Revegetation Plan assesses the works that were implemented to improve vegetation quality and habitat at the site.

This review has been carried out to provide objective information about the scientific research associated with delivery of the plan. The results will be considered in the development of the next Management Plan.

Introduction

The Grey-headed Flying-fox *(Pteropus poliocephalus)* (GHFF) is endemic to south-eastern coastal Australia, from Maryborough, Queensland, though New South Wales to southwest Victoria.

Grey-headed flying foxes are nationally threatened and listed as endangered in Victoria. This is due to population declines resulting from threatening processes such as habitat destruction, roost disturbance, and culling. The species is highly mobile and genetic exchange occurs across the entire geographic range of the species. For this reason the entire Australian population is considered to be one single interbreeding population.

GHFF have been an occasional visitor to the Melbourne area since 1884, although it wasn't until 1986 that a permanent camp was established at the Royal Botanic Gardens Melbourne (RBGM).

This newly-formed Melbourne camp was located 450 km west from the closest known colony at the time (located near Mallacoota, Victoria). This 450 km expansion of the GHFF range may have been due to a combination of local climate change (the city is now warmer, with less frost and higher humidity; as well as increased diversity, abundance, and availability of food resources). Smaller camps also occur in Geelong and East Gippsland (Bairnsdale, Dowells Creek, Karbethong and Swans Track). GHFF will form camps, usually near water, often in dense stands of native vegetation. During summer these camps may consist of several thousand individuals, however over winter adults will disperse up to 1000 km away, though some will remain in winter camps when food is plentiful.
At night, GHFF forage for nectar, pollen and fruit; sometimes travelling up to 50 km from their camp to feed.

To avoid further damage to the culturally significant Royal Botanic Gardens Melbourne, GHFF were relocated to Yarra Bend Park, Kew in 2003. Since 2004, the Australian Research Centre for Urban Ecology (ARCUE) has been undertaking a research and monitoring program at the Yarra Bend campsite.

Although Melbourne's Yarra Bend Campsite represents a relatively modest proportion of the total GHFF population (the national population of GHFF was estimated at 674,000 in 2005) it is clear that urban areas are becoming increasingly important for GHFF. There are flying-fox camps (GHFF, Black Flying-fox, Little Red Flying-fox) within or in close proximity to urban centres in eastern and northern Australia (such as Melbourne, Sydney, Brisbane, Darwin and other smaller towns in eastern Australia). It is thought that GHFF have moved further into urban areas as a result of the large-scale clearing and fragmentation of the species natural habitat, and the availability of food sources and suitable climatic conditions in these areas. Urban areas offer a more reliable food source (120 plant species, native to Queensland and NSW, which are favoured by GHFF have been planted in Melbourne's parks and streets), provide protection from shooting, and street lighting may provide easier navigation. However, the modified environment of urban areas limits the available choices of roosting sites for flying-foxes. Thus the appropriate management of existing campsites (including the provision of new roosting opportunities) within urban areas is important for the conservation of GHFF in Victoria and across Australia.

Data collection and results

Research and monitoring themes

Since 2004, the Australian Research Centre for Urban Ecology (ARCUE) has been undertaking a research and monitoring program at the Yarra Bend campsite.

This research work has two broad research themes:

- Camp and population dynamics
- Roost and camp conditions (see Table 1) .

The first theme investigated the camp and population dynamics at Yarra Bend and other camps across Victoria, and the second theme focused on vegetation and microclimate condition within camps. This report summarises the outcomes of selected key themes to enable a review of the Flying-fox Campsite Management Plan and support the consultation process for the development of the next Management Plan.

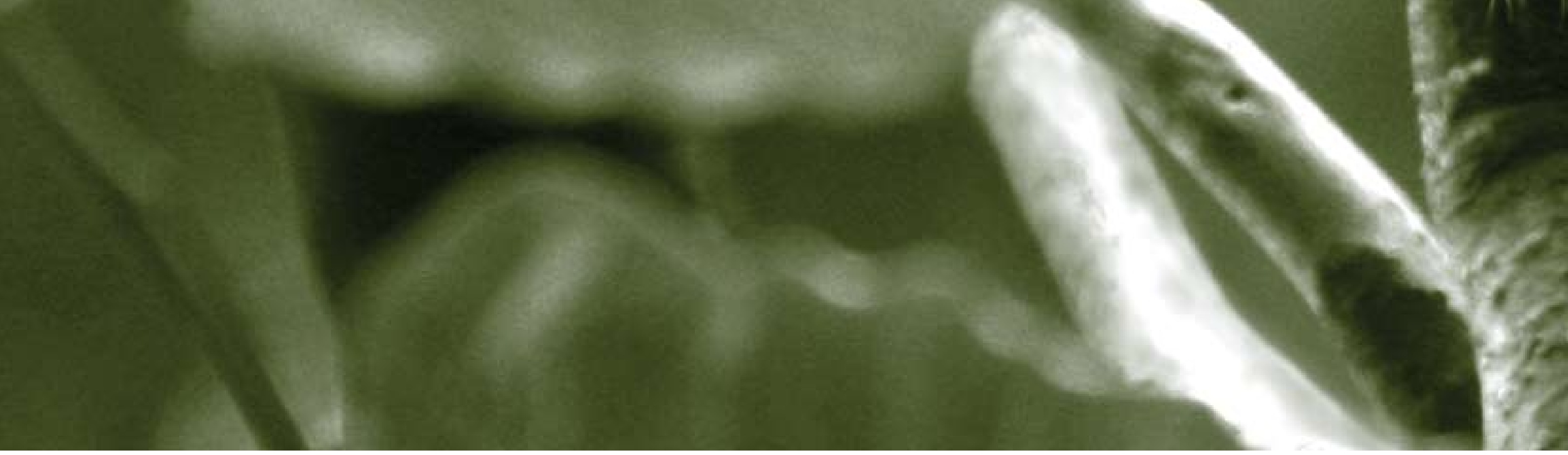


Table 1. Broad themes of research and monitoring of the Grey-headed Flying-fox camp at Yarra Bend Park, Kew

Research Theme 1: Camp and population dynamics	
Flying-fox population size	1 The number and distribution of GHFF at Yarra Bend Park and at other Victorian camps. 2 The reproductive output at Yarra Bend Park.
Flying-fox mortality	1 Rate of mortality at Yarra Bend Park. 2 Rate of mortality at Yarra Bend Park (and other Victorian camps) as a result of heat events.
Research Theme 2: Roost and camp conditions	
Vegetation condition and tree health	1 To quantify the extent to which GHFF and management actions (e.g. revegetation works, construction of wetlands) alter the species composition and health of the vegetation at Yarra Bend. 2 To quantify basic parameters of roosting GHFF (e.g. angle and diameter of roosting branches) for the design of artificial roosting structures. This is a potential measure to reduce the impact of roosting flying-foxes on the vegetation.
Effect of camp management on microclimatic conditions	To quantify the microclimatic conditions within GHFF camps (Yarra Bend Park, Geelong, and East Gippsland camps) to assist in understanding patterns in camp occupancy.

Camp and population dynamics

Figure 1

Number of GHFF roosting at Yarra Bend Park. Solid squares are static count results, while open diamonds are from fly-out counts.

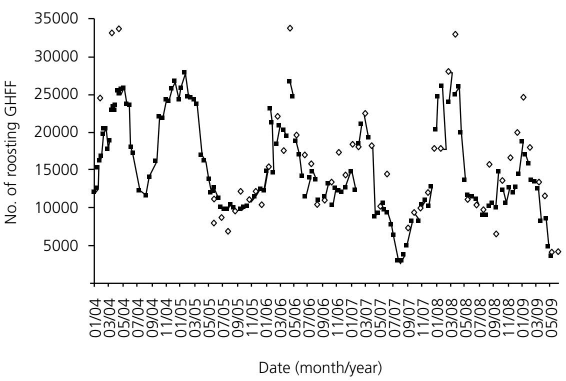
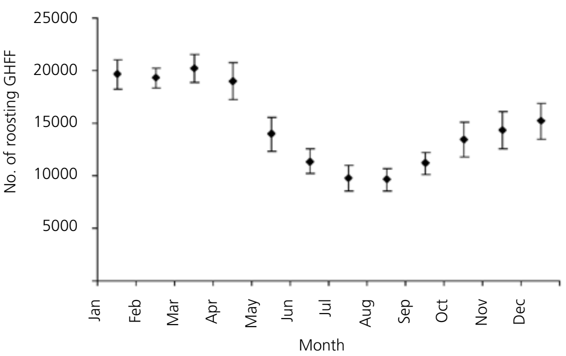


Figure 2

Seasonal pattern in number of GHFF roosting at Yarra Bend Park. Data presented is the mean number of individuals recorded each month from static counts (± 1 s.e.).



Number and distribution of Grey-headed Flying-foxes

One of the most basic requirements when managing a population of wildlife is to have good knowledge of the size of the population and its distribution. There are two main approaches to assessing the size of colonies of flying-foxes:

1. Static counts (when the number of roosting flying-foxes is counted from the ground by a single observer during the day); and
2. Fly-out counts (when a group of observers are strategically located around the camp and each observer counts the flying-foxes as they leave the roost at dusk).

Both methods have inherent biases, and it is difficult to determine which method is the most accurate. Thus, to ensure the most reliable results, both static counts (at least twice per month) and fly-out counts (once per month) have been conducted at Yarra Bend Park since the colony was established in 2003.

The camp at Yarra Bend Park has been permanently occupied since 2003 after being relocated from RBGM. The number of flying-foxes within the camp varies seasonally and annually (see Figures 1, 2), and also depending on the counting method used.

Nevertheless, the seasonal pattern is predictable and similar for both types of counts, with peaks in number from January to April, reducing to the lowest point in July and August. The peak in summer/autumn is approximately 20,000–27,000 for static counts, and up to 30,000–35,000 for fly-out counts. The minimum population size is typically around 10,000 flying-foxes, but reaching as low as approximately 5000 flying-foxes in mid-2007, and reaching similarly low numbers in mid-2009 (Figure 2).

Accuracy and reliability of counts

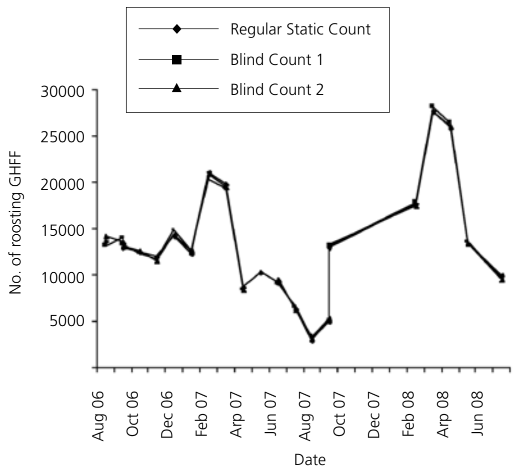
Because there is an inherent bias with all methods of counting flying-foxes, a combination of both fly-out counts and static counts have been used at Yarra Bend Park to give the most reliable data possible on the number of flying-foxes within the camp. Static counts are conducted twice per month by a single observer and fly-outs once per month by 10–20 volunteers with a mix of experience. As the identity of the fly-out volunteers is different each month, it is difficult to assess count to count variation. However, because a single observer does static counts, it was possible to assess the reliability of the static counts.

The reliability of static counts was assessed by the regular observer, who conducted a second and third static count once a month for two years. The second and third counts at this time were 'blind', in that the observer did not sum up the results himself. Rather, the raw data from the blind counts were forwarded to a second researcher who tallied the scores. The results were not shared with the regular counter until the end of the two-year period. The estimates of the number of GHFF roosting at Yarra Bend Park were very similar among the regular static count and the two blind static counts (see Figure 3). This demonstrates that static counts, conducted by a single, experienced observer at Yarra Bend, are very repeatable or consistent.

Figure 3

The similarity between two 'blind' static counts and one regular static count.

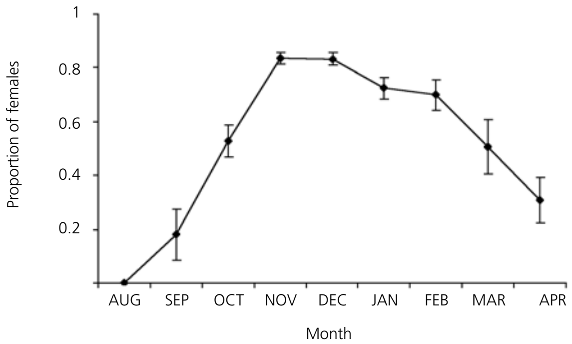
All three static counts were conducted on the same day by a single observer, and the results of the blind count were not revealed to the observer until after all counts were completed.



Camp and population dynamics

Figure 4

Mean proportion of females with young at Yarra Bend Park per month (± 1 s.e.). Data is from the 04/05, 05/06, 06/07, 07/08 and 08/09 breeding seasons.



Reproductive output

Since 2004, surveys of the Yarra Bend flying-fox colony have been conducted to determine female reproductive output. Flying-foxes have a slow life-history, which means that they only produce a single pup annually; however they have a long reproductive lifespan. Females generally do not reach full sexual maturity until three years of age. It is thought that during unfavourable conditions (e.g. when resources are limited), female flying-foxes might maximize their own fitness by foregoing reproduction, thus enhancing their chances for survival and future reproduction. Estimating reproductive output is an important element in understanding the demographic status of GHFF populations. Reproductive output counts are carried out every 10–14 days from late August/early September until mid-March/late April. During these surveys, the sex and reproductive condition (carrying or closely associated with a juvenile flying-fox) of individuals is assessed.

The first births each year are usually recorded in early September, and by late October and early November an average of approximately 85% of females are carrying young (Figure 4). The average number of females with young declines to about 40–50% by mid-April each year. During the 2008/09 breeding season 28% of females were carrying young in late September and by mid-November there were 91% females with young. By early April, 13% of females were carrying or were associated with (hanging next to) a juvenile flying-fox. The reproductive output results suggest that the Yarra Bend colony has a consistent annual birth rate, which is similar to findings from other studies, which have found that approximately 80–90% of female flying-foxes produce one young each year.

Male to female sex ratios

The number of males is also recorded during the reproductive output surveys in order to give an estimate of female to male sex ratio during the breeding season. Studies on sex ratio variations help to understand the social organisation and dispersal behaviour of GHFF. The average ratio of male to female GHFF during the breeding season at Yarra Bend Park (Oct 2004 – April 2009) is 0.83. That is, there are 0.83 males to each female.

The overall bias towards females in the colony varies seasonally, with a greater proportion of males at the beginning of the birthing season (September/October) and after young are weaned (March/April) (Figure 5).

Rate of mortality within the Yarra Bend camp

Since January 2006 there have been searches for dead flying-foxes within the Yarra Bend camp at approximately fortnightly to monthly intervals and also following heat events. The date of death of each flying-fox is estimated based on the level of decomposition and whether the dead flying-fox was found soon after a heat event. Estimating the annual rate of mortality is important in understanding the demographic status of GHFF population. Figure 6 displays the predicted dates of deaths for flying-foxes found between January 2006 and May 2009; it also includes dates when no dead flying-foxes were found to emphasize the large numbers of deaths caused by heat events over the summer months. During 2008/09 the highest number of deaths occurred between December and February, this is consistent with previous years. Mortality rates are generally very low between late February and November/December.

Figure 5

Mean male: female GHFF sex ratios for weekly to fortnightly intervals (± 1 s.e.).

Data is from the 04/05, 05/06, 06/07, 07/08 and 08/09 breeding seasons.

A sex ratio of 1.2 equals 1.2 males to 1 female.

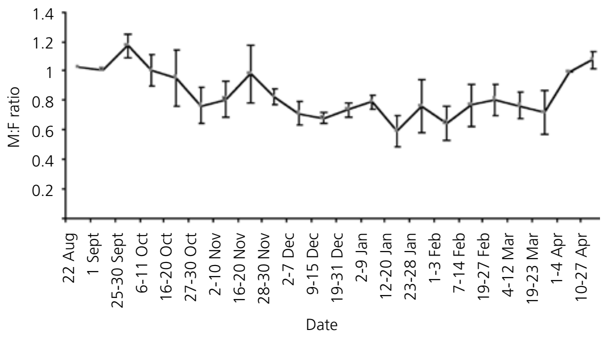
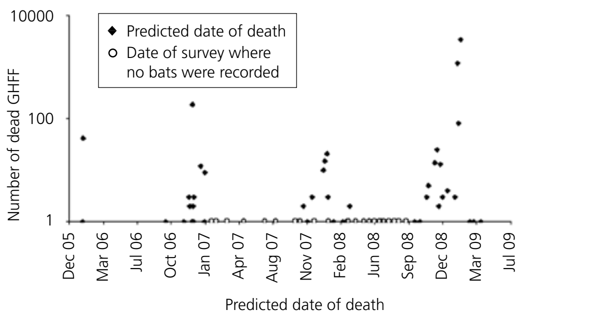


Figure 6

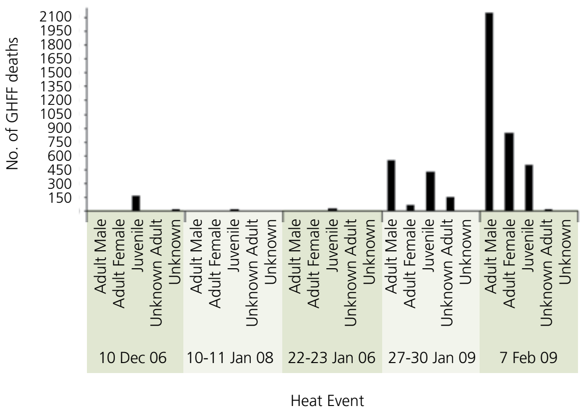
The predicted dates of deaths for dead Grey-headed Flying-foxes found during mortality surveys (between January 2006 and May 2009) at Yarra Bend Park.



Camp and population dynamics

Figure 7

The sex and age of flying-foxes collected after major heat events (2006–2009) at different stages over summer, at Yarra Bend Park.



Rate of mortality as a result of heat events

Flying-foxes are particularly sensitive to the effects of extreme temperatures, as they roost among the exposed branches of canopy trees. During January and February 2009, 4868 flying-foxes died as a result of two major heat events. A four-day heatwave from 27–30 January 2009 resulted in 1213 deaths, and on 7 February 2009, 3539 flying-foxes died as a result of extreme temperature (a maximum of 46.4°C). Prior to this, the largest number of heat-related GHFF deaths recorded at Yarra Bend Park was 192 (on 10 December 2006, a maximum temperature of 42.1°C). See Table 2 for the numbers of GHFF that died during these heatwaves. The number of GHFF deaths recorded at Bairnsdale and Geelong camps during these two heat events are presented in Table 3.

The mass mortality of GHFF during extreme heat events has been recorded at other campsites in eastern Australia; with evidence for at least 19 other heat-related mortality events since 1994, resulting in over 24,000 GHFF deaths. One example includes the death of 4800 GHFF after an extreme heat event in Sydney, NSW (in early January 2006; max temperature 44.4–45.2°C). Before 1994, there is only evidence of three mass die-offs in eastern Australia, suggesting that these events have recently become more common and could be attributed to local climate change. However, recent die-offs are also more likely to be reported, due to increased environmental awareness and more colonies being formed near urban areas. During both heat events at Yarra Bend Park in 2009, GHFF were observed to display behaviours such as wing fanning, seeking shade in golf course trees (mainly cypress pines) and trees further along the Yarra River, and panting. These behaviours are thought to help maintain body temperature and have been recorded elsewhere during such heat events.

Throughout the 2009 heat events, information including sex, age (adult or juvenile) and forearm length was collected from a random selection of dead flying-foxes. This data is useful for determining which individuals (juveniles or adults, males or females) are more susceptible to extreme weather conditions. For both the 2009 January and February heat events, more adult males were found dead than adult females and juveniles at Yarra Bend Park (see Figure 7). This pattern was also evident among the dead flying-foxes collected at the Bairnsdale and Geelong camps.

It appears that juveniles and adult females appear most vulnerable to high temperatures that occur in December and early January (females are lactating and young are still been weaned). In contrast, high temperatures in February appear to cause higher mortality in adult males (possibly related to higher levels of testosterone for mating).

Research on GHFF mortality rates during heat events is important for understanding the impact of extreme temperatures on population dynamics.

Table 2.

The estimated date of death for flying-foxes collected after two major heat events (27–30 January and 7 Feb 2009), at Yarra Bend Park. Note - temperatures are recorded from the data loggers at Bellbird Yarra Bend Park.

* The individuals in these categories were found days to weeks after the heat event and the extent of decomposition prevented us from confidently assigning a date of death.

** Percentages of total population are based on static counts carried out on the 19/1/2009 and the 1/2/2009 at Yarra Bend; colony sizes were 16,920 and 15,770 respectively.

Estimated date of death in 2009	Max temperature (degrees Celsius)	No. of dead GHFF (% of total population**)
27th Jan	36.6	200 (1.2%)
28th Jan	43.5	434 (2.6%)
29th Jan	44.7	330 (1.9%)
30th Jan	44.4	51 (0.3%)
January heat wave (27–30th Jan)*		198 (1.2%)
7th Feb	46.6	3539 (22.4%)
Either heat event (27–30th Jan or 7th Feb)*		116

Table 3.

The estimated date of death for flying-foxes collected after two major heat events (27 – 30th January and 7 Feb 2009), at Bairnsdale and Geelong camps. Note - temperatures are recorded from the data loggers on site.

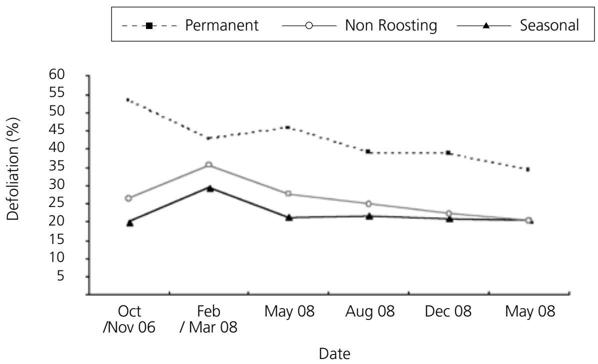
* For the Bairnsdale camp, the percentages of total population are based on a static count carried out on the 26/1/09; the colony size was 2,720. For Geelong, percentages are based on fly-out counts carried out on the 7/1/2009 and the 4/2/2009; colony sizes were 2,400 and 3,500 respectively.

Estimated date of death in 2009	Max temperature (degrees Celsius)		No. of dead GHFF (% of total population**)	
	Bairnsdale	Geelong	Bairnsdale	Geelong
27th Jan	29.3	31.6	–	–
28th Jan	39.6	39.6	–	66 (2.75%)
29th Jan	43.3	46.1	–	136 (5.7%)
30th Jan	43.5	39.5	4 (0.1%)	–
7th Feb	46.0	46.3	329 (12.1%)	53 (1.5%)

Roost and camp conditions

Figure 8

The differences in defoliation (percentage of foliage lost) for trees in permanent, non-roosting and seasonal roosting areas at Yarra Bend Park; and the changes in defoliation over a period of time.



On-site tree assessments

Dieback and defoliation of canopy trees used by roosting flying-foxes is a common occurrence at flying-fox campsites. The weight and movement of flying foxes, while they are roosting, can strip leaves off trees and result in broken branches. Monitoring the health of roost trees is important to inform appropriate management of the campsite by identifying which sections of the campsite may need to be restored. To determine the rate of roost tree defoliation at Yarra Bend Park, on-site tree assessments have been carried out every 4–5 months since October 2006.

A transect line, approximately 2.5 km long, is located along each side of the Yarra River approximately 10 m from the river edge. Along this transect 199 trees have been selected for repeated observations; these trees are located within the permanent roosting area, in the outer seasonal roosting areas which are utilised during summer, and in non-roosting areas just outside the flying-fox colony.

The condition of the canopy of roost and non-roost trees was determined by scoring the extent of defoliation (percentage of foliage lost) as a category from 1 (0–25% of foliage lost) to 4 (75–100 % of foliage lost). Dead trees were scored as -1.

This has proved to be an effective method which can be repeated by different observers. The percentage of dead branches and new foliage is also recorded during these surveys.

The results from this study suggest that flying-foxes are having an impact on roost trees, causing over 50% defoliation for some trees within sections of the campsite permanently occupied by GHFF. The percentage of defoliation differed among the three different kinds of roosting areas, with a statistically significant higher rate of defoliation for trees in the permanent roosting area (see Figure 8).

Trees that were used as roosts only during the summer months will generally get a chance to recover and develop new growth over spring/winter. In contrast, many trees in the permanent roosting area are under constant stress, causing the death of several large branches in this section of the campsite.

There were also changes in the rate of defoliation over the last three years, especially for trees within the permanent roosting area, where the percentage of defoliation appears to be decreasing over time (see Figure 8); these trees may have developed new growth (or epicormic growth). Epicormic growth often appears on trees after stresses/disturbances such as fire and defoliation, and is an indication of tree recovery.

Other studies have found that colonies of roosting flying-foxes will gradually shift and occupy different parts of the available habitat over time, thus allowing recovery of the tree canopy. A similar pattern may be occurring at Yarra Bend Park, although this is yet to be confirmed.

Photo analysis

A second method is also used to further quantify the health of roost trees. This method can also be easily repeated by any observer. Along the 2.5 km transect line 61 permanent plots (marked by a wooden stake) are set up at approximately 50 m intervals. At each of these stakes canopy photos are taken. Since March 2007, these photos have been taken every 4–5 months.

Photos are taken in permanent, seasonal and non-roosting areas. The photos are downloaded onto the computer and a grid of one hundred points is overlaid on the photo on-screen. The number of leaves, flying-foxes, sky and branches (fine and large) at each grid point is counted. These values can then be translated into an index of cover. After repeated sampling, these photos can be used to determine the difference in leaf cover between roosting and non-roosting areas, and the change in leaf cover over time.

The latest analysis (including recent photos taken in May 2009) shows that there is a lower percentage of leaf cover in permanent roosting areas, when compared to seasonal and non-roosting sites (see Figure 9). This result is consistent with the on-site tree assessment results. However, there was no significant change in leaf cover over time.

Figure 9

Three representative examples of tree canopies at Yarra Bend Park: (1) is located in a non-roosting area just outside the flying-fox colony; (2) is used as a seasonal roost during summer; and (3) is permanently occupied by flying-foxes. All three photos were taken in May 2009.

1. Non-roost

2. Seasonal

3. Permanent

Roost and camp conditions

Artificial roosts

One option often identified as a potential measure to reduce the impact of roosting flying-foxes on the vegetation is to provide artificial roosting structures. Artificial roosts are structures that provide roosting opportunities for flying-foxes. They may be as simple as ropes suspended among the trees, or as elaborate as engineered structures with multiple arms and cables, similar to a multi-storey Hills hoist clothesline.

However, before designing and testing the suitability of certain structures, it is essential to have a good understanding of the roosting behaviour of flying-foxes within the target camps. The aim of this research component was to quantify basic parameters of roosting GHFF, specifically:

- type, angle and diameter of roosting branch
- height of flying-fox in the tree and height of surrounding vegetation and
- maximum, minimum and average distance to the next closest flying-fox.

The roosting behaviour of GHFF was quantified at Yarra Bend Park and Geelong camps in winter and spring 2008, summer 2008/09, and autumn 2009. At each site, a randomly located focal flying-fox was identified and its roosting behaviour recorded. The roosting parameters of the next closest flying-fox was then assessed, until 20 individuals were sampled. Next, another initial focal flying-fox was randomly selected until 20 groups, each with 20 individuals, had been sampled, to a total of 3200 observations.

The research data indicates that if 20% of GHFF colony (5000 flying-foxes) required roosts this would equate to approximately 3.1 km of roosting space. This makes this option logistically impractical at Yarra Bend Park. In the future, artificial roosts may still have merit in very specific circumstances, such as the protection of certain high-value trees in garden settings.

Climatic conditions within selected camps

Climatic conditions play an important role in the dynamics of flying-fox camps. One of the hypotheses explaining the establishment of the permanent camp in Melbourne has been the warming of Melbourne. Recent deaths of large numbers of flying-foxes at Yarra Bend Park (and other camps in Victoria and Australia) due to excessive heat have also prompted queries into the importance of microclimatic conditions on flying-fox survival. Furthermore, most camps of GHFF are located near to a water source, suggesting that humidity may be an important factor influencing the suitability of sites as camp locations.

To explore the importance of microclimate at the camp sites, loggers were installed to record temperature and humidity at 15 minute intervals. There is now more than three years of data from Yarra Bend Park, Geelong, Royal Botanic Garden Melbourne (RBGM), and four camps in East Gippsland. The temperature and humidity data across all camps for the most recent heat events (late January 2009 and 7 Feb 2009) was extracted to characterise the conditions on those days and compare among camps.

The maximum temperatures experienced at each of the camps varies, with maximums typically recorded at Yarra Bend Park and minimums recorded in East Gippsland (see Table 4). Geelong, RBGM, Bairnsdale and Yarra Bend Park reached > 40 degrees in both late January and February 2009. Minimum relative humidity recorded at the camps follows a similar but reversed pattern, with the hottest camps also experiencing the lowest levels of relative humidity. Further analysis of the large data set may enable us to identify the combination of temperature and humidity at which GHFF begin to struggle. It is likely that an increase in understorey/mid-storey vegetation at Yarra Bend Park, plus efforts to restore the tree canopy, will be effective at reducing temperature and increasing humidity. However at this stage, the combination of temperature and humidity which may reduce or prevent heat-related mortality is not known.

Table 4.

Mean maximum temperature and mean minimum relative humidity at each GHFF camp in Victoria at two heat events (late January 2009 and 7 February 2009). Data presented are the mean from 3 loggers (except Yarra Bend Golf course with 4 loggers) positioned within the canopy (i.e. at typical roost height for that camp).

Maximum Temperature at each camp							
	27/01/09	28/01/09	29/01/09	30/01/09	6/02/09	7/02/09	8/02/09
Dowells Creek	26.8	35.8	37.8	35.6	28.4	40.9	25.6
Geelong	31.6	39.6	46.1	39.5	26.3	46.3	22.4
Yarra Bend Golf Course	37.3	44.2	45.6	45.8	30.9	47.3	22.4
Bellbird, Yarra Bend Park	36.6	43.5	44.7	44.4	30.2	46.6	22.0
Karbethong	27.2	35.8	38.4	36.5	24.9	40.9	27.9
Swans Track, East Gippsland	32.3	37.6	41.8	41.7	25.1	44.6	26.0
Bairnsdale	29.3	39.6	43.3	43.5	24.9	46.0	29.0
RBGM	34.1	41.1	42.6	42.7	27.2	45.0	21.3

Minimum Relative Humidity at each camp							
Dowells Creek East Gippsland	59.9	39.5	21.5	24.6	57.1	30.9	59.4
Geelong	41.0	20.5	16.2	27.1	56.7	12.7	46.2
Yarra Bend Golf Course	13.6	9.9	14.1	12.1	34.5	10.1	52.2
Bellbird, Yarra Bend Park	13.8	11.1	14.9	12.9	35.3	10.5	52.5
Karbethong	60.2	27.6	23.7	28.5	64.4	30.5	52.7
Swans Track, East Gippsland	42.5	26.2	16.1	17.1	61.1	14.5	55.9
Bairnsdale	45.1	22.2	16.5	16.5	66.7	12.5	46.0
RBGM	18.2	14.4	18.2	15.9	41.5	12.9	57.5

Future management activities

Based on the scientific research data, the following management activities are proposed:

- Continue planting indigenous grasses and understorey plants, this may help contribute to the health of roost trees.
- Plant more trees for future roosting opportunities, amongst existing roost trees as well as in sparse areas further up the Yarra River. This will give flying-foxes the opportunity to move into new roost trees, allowing existing trees to recover.
- Continue research on artificial roosts. Artificial roosts could be trialled in specific areas as alternative roosting habitat to help ameliorate the effects of defoliation on roost trees, and avoid the potential death of these trees.
- During the two major heat events in 2009, many flying-foxes moved to a few large cypress pines on the golf course that were close to the riverside campsite, as a result large numbers of GHFF were clustering within these trees causing a high number to suffocate and overheat. To avoid dispersal to and clustering in these nearby cypress trees, more shrubs and small trees (particularly Silver Wattle) could be planted, especially in areas with little mid-storey on the golf course side of the Yarra River. This may provide more roosting opportunities/shelter during future heat events.

Future research

Ongoing research is important for understanding population dynamics and roosting requirements of GHFF at Yarra Bend Park. Information gained from this research is essential to inform the appropriate management of this GHFF camp.

It is recommended that the following research should continue:

- Static counts, twice per month.
- Fly-out counts, once per month.
- Mortality surveys, twice per month.
- Reproductive output, 10-14 day intervals.
- Camp microclimate surveys.

Potential amendments to current research are:

- Sex ratio surveys could also be undertaken outside of the breeding season (May–August); the male to female sex ratio for this period is currently unknown.
- Tree heath assessments could be carried out less regularly; once or twice a year should be enough to see a change in defoliation.
- Humidity loggers could also be placed low in the vegetation at wetland areas to assess the impacts of the wetlands on camp microclimate.

Potential additional research:

- Documentation of preferred roosting trees (collect extra data during counts) could have future implications for campsite management
- Using satellite collars, investigate GHFF movements within their feeding range, to see in more detail where they are feeding (for example are certain foraging sites favoured over others). This could also be carried out at Geelong and East Gippsland camps.
- Continue tagging flying-foxes with thumb bands to determine the proportion of GHFF that return to the colony after seasonal dispersal; which individuals (sex/age) stay during winter; and which individuals are susceptible during heat events (For example, are the heat susceptible flying-foxes Melbourne permanents or migrants from other camps?).
- Investigate the role of GHFF as pollinators/seed dispersers in urban areas. GHFF are thought to be critical to forest ecology, assisting to regenerate our diminishing forests, but is their role as pollinators important in highly fragmented urban areas?
- In February 2008, 340 Little Red Flying-foxes *Pteropus scapulatus* (LRFF) were recorded at Yarra Bend Park (these individuals were likely migrants from a campsite near Numurkah). Research on the population dynamics of this population would be beneficial for the management of the Numurkah camp. It would also be valuable to determine their foraging range using satellite tracking.

Potential additional research during heat events:

- A better management system needs to be designed and implemented that incorporates collection and processing of dead flying-foxes, transport and disposal.
- The location of dead flying-foxes across the camp needs to be mapped more accurately, to allow for comparisons among preferred roost locations (e.g. locations resulting in more/less deaths).
- Monitor the effectiveness of spraying individual flying-foxes by volunteers (monitor disturbance/estimate percentage that survive).
- Additional information could be collected from GHFF during such events. Access to large numbers of recently-dead flying-foxes is a valuable opportunity to answer ecological and biological questions that would otherwise be costly to answer. This could include: teeth extraction to measure cementum layers and accurately determine the age of adults; extracting DNA (tissue samples) to compare levels of relatedness among dead individuals and movement patterns among all GHFF camps (genetic samples are now routinely collected during trapping events); and take blood samples to potentially determine hormone levels in dead flying-foxes (e.g. testosterone levels in male flying-foxes during the later part of summer).

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