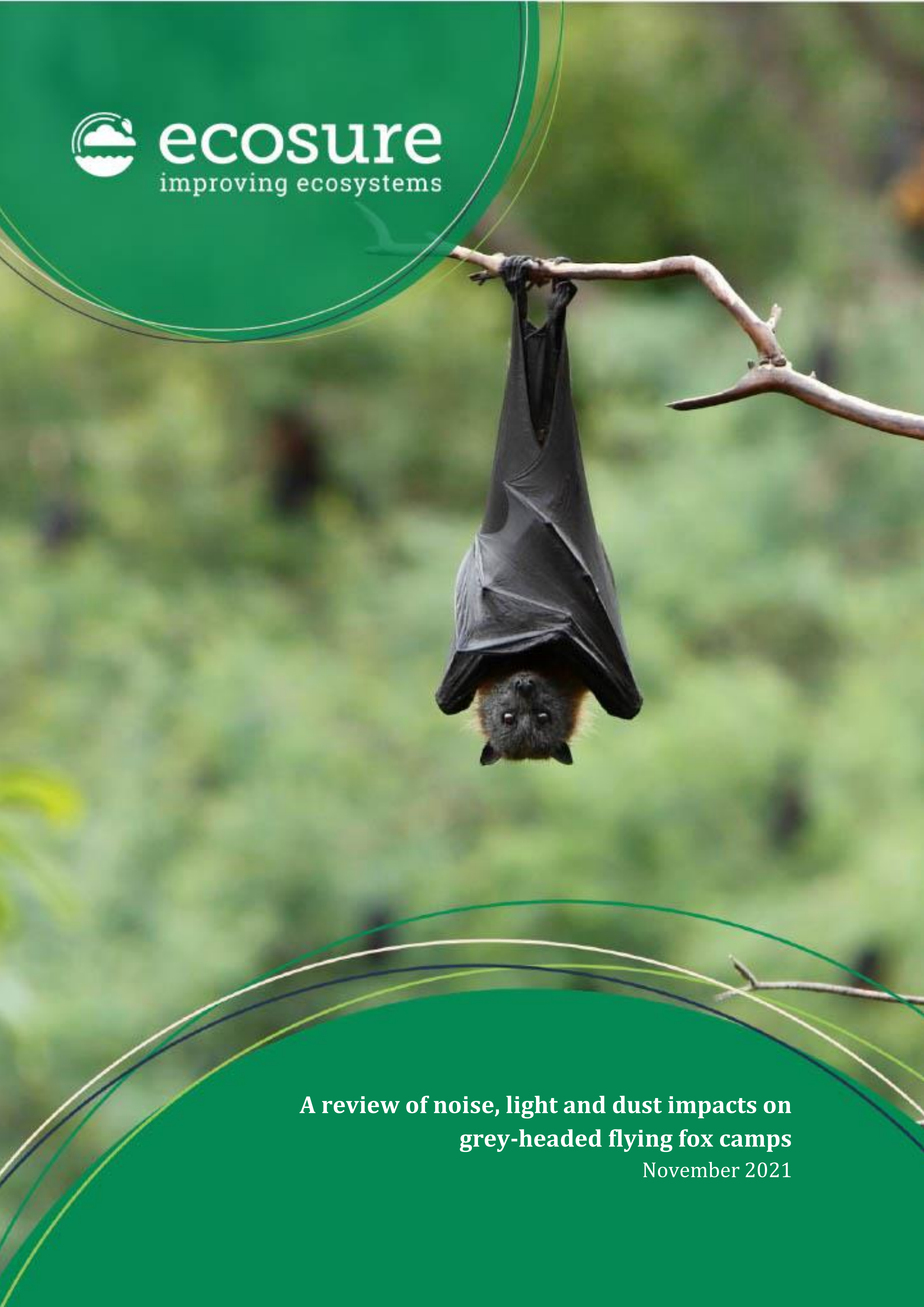

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A review of noise, light and dust impacts on grey-headed flying fox camps

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Acknowledgement of Country

We acknowledge the Traditional Custodians of Australia and their continuing connection to land and sea, waters, environment and community. We pay our respects to the Traditional Custodians of the lands we live and work on, their culture, and their Elders past and present.

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1 Introduction

The grey-headed flying-fox (*Pteropus poliocephalus*; GHFF) is one of the world's largest bats and is endemic to Australia. The GHFF is listed as Vulnerable in New South Wales and the Australian Capital Territory, Rare in South Australia and Threatened in Victoria. It is also listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), making it a Matter of National Environmental Significance (MNES).

The GHFF historically occupied the coastal belt between central Queensland and Victoria, recently extending into more inland areas and south-west to Adelaide (DAWE 2021b). Given its nomadism and mobility, the species is considered to have a single national population (DAWE 2021a). Individuals travel thousands of kilometres among a network of camps across their range (Welbergen et al. 2020a) to forage on the blossom and fruit of more than 100 native species (Eby et al. 2019). As with other flying-foxes, the GHFF plays a critical role in long-distance seed dispersal and pollination, contributing to the health, longevity, and diversity within and among vegetation communities (Southerton et al. 2004; Westcott et al. 2008; McConkey et al. 2012). Protection of the GHFF and its habitat contributes to sustaining ecological processes along the east coast of Australia, including 3 World Heritage Areas (DAWE 2021a).

Common amongst naturally long-lived species, flying-foxes are slow to reach sexual maturity and have a low reproductive rate, generally producing only one pup per year. This means the GHFF has limited capacity for population increase, even under ideal conditions (McIllwee and Martin 2002), which limits their ability to recover from population level impacts caused by threatening processes (DAWE 2021a). Research on threatening processes is often focused on direct threats and causes of mortality, however, less is known about the potential effect of indirect impacts on the GHFF, such as unintentional disturbance at camps which may be caused by noise, light and dust.

1.1 Purpose

This document has been developed to assist the Australian Government Department of Agriculture, Water and the Environment and project proponents in determining the potential for noise, light and dust to impact on the vulnerable GHFF. The document is designed to be an additional source of information to the statutory documents. It is not a statutory document or policy statement. If information diverges, the information in the statutory document(s) and policy statement(s) for the GHFF take precedence over this document. This document should be used in parallel with the Significant Impact Guidelines 1.1 – Matters of National Environmental Significance (DoE 2013) (Significant Impact Guidelines), the GHFF Recovery Plan (DAWE 2021a) and Referral Guideline (DoE 2015) in determining the significance of all potential impacts on the GHFF.

1.2 Scope

This document focuses on potential impacts on GHFF at their camps associated with:

- noise
- light

- dust.

It should be noted that impacts associated with noise, light and dust can be either indirect or direct. For example, noise associated with construction can disturb flying-foxes at their camp (i.e. a direct impact), or could have more subtle or secondary impacts, such as interfering with effective communication which may reduce reproductive success (i.e. an indirect impact). For the purposes of this document both indirect and direct impacts will be collectively termed ‘impacts’, and the proponent and the department should consider both in relation to the many variables associated with an individual project.

It is acknowledged that noise, light and dust, and other unintentional disturbance have the potential to impact GHFF at their foraging habitat (see DAWE 2021a and Eby et. al. 2019). While potential impacts from noise, light or dust to foraging habitat is largely beyond the scope of this document, they must be considered by proponents and the department assessment officers to determine the significant impact on the species. This is particularly important when there is overlap between the proposed action area and ‘foraging habitat critical to the survival of the GHFF’ as defined in the National Recovery Plan (DAWE 2021a). Areas for future research and other potential impacts (e.g. altered water regimes, airborne metals) have also been noted.

Publicly available information and unpublished data were reviewed in the development of this document. The nature and potential sources of these impacts on flying-foxes are described, along with case studies as evidence of how flying-fox camps can be impacted.

1.3 Limitations

There is a paucity of literature and data available on impacts from noise, light and dust on the GHFF. Available information has been summarised in Section 2, and parallels with other species have been provided where relevant e.g. other flying-fox species, bats in general or, animals considered to share similar biology (e.g. lung capacity) or traits (e.g. pollinators). The lack of available information and understanding of these potential impacts lends itself to the adoption of the precautionary principle, and further monitoring and research is required to refine this document and impact avoidance/mitigation measures.

1.4 Legislation and guidelines

Under the EPBC Act, an action will require approval from the Commonwealth Government Minister for the Environment (the minister) if the action has, will have, or is likely to have, a significant impact on an MNES. As a nationally vulnerable species, the GHFF is an MNES protected under the EPBC Act.

The Significant Impact Guidelines outline a ‘self-assessment’ process to assist proponents in deciding whether referral to the Minister is required.

As per the Significant Impact Guidelines, an action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

- lead to a long-term decrease in the size of an important population of a species
- reduce the area of occupancy of an important population
- fragment an existing important population into 2 or more populations

- adversely affect habitat critical to the survival of a species
- disrupt the breeding cycle of an important population
- modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
- result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat
- introduce disease that may cause the species to decline, or
- interfere substantially with the recovery of the species.

The GHFF is considered a single, mobile population across its range (DAWE 2021a). The risk of a significant impact is increased at nationally-important camps as they contain a significant proportion of the population. The EPBC Act Policy Statement *Referral Guideline for Management actions in grey-headed and spectacled flying-fox camps* (DoE 2015) (Referral Guideline) defines a nationally-important GHFF camp as one that has been occupied by:

- ≥ 10,000 GHFF in more than one year in the last 10 years; or
- > 2,500 GHFF permanently or seasonally every year for the last 10 years.

Sub-section 75(2) of the EPBC Act requires that the minister, when deciding whether an action is a controlled action, considers 'all adverse impacts (if any)' the action has, will have, or is likely to have, on protected matters. Section 527E defines the 'impact' of an action as an event or circumstance which is:

- a direct consequence of the action; or
- an indirect consequence of the action, if the action is a substantial cause of the event or circumstance.

Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment that is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts (DAWE 2021). This document provides information to assist proponents in determining whether a significant impact is 'likely', in line with the Significant Impact Guidelines and Referral Guideline. The Significant Impact Guidelines states that it should not be concluded that 'a significant impact is not likely to occur because of management or mitigation measures unless the effectiveness of those measures is well-established (for example through demonstrated application, studies or surveys) and there is a high degree of certainty about the avoidance of impacts or the extent to which impacts will be reduced'.

1.4.1 Other guidelines

Other guidelines reviewed to inform this document are listed in Table 1.

Table 1 Guidelines consulted

Type of stimuli	Guideline
Dust (WA)	A guideline for managing the impacts of dust and associated contaminants from land development sites, contaminated sites remediation and other related activities (DEC 2011)

Type of stimuli	Guideline
Dust (Qld)	Guideline for management of respirable dust in Queensland mineral mines and quarries Mining and Quarrying Safety and Health Act 1999 version 3 April 2020 (DNRME 2020)
Noise (Commonwealth)	National Code of Practice for Noise Management and Protection of Hearing at Work 3rd Ed. (NOHSC 2004)
Noise (Qld)	Transport Noise Management Code of Practice (TMR 2016)
Light (Commonwealth)	National Light Pollution Guidelines for Wildlife including marine turtles, seabirds and migratory shorebirds (DEE 2020)
Light (Commonwealth)	National Light Pollution Guidelines, Appendix I Bats (unpublished) (DAWE 2021b)
General (Qld)	Code of Practice: Low impact activities affecting flying-fox roosts (DES 2020a) Code of Practice: Ecologically sustainable management of flying-fox roosts (DES 2020b)
General (NSW)	Flying-fox Camp Management Policy 2015 (OEH 2015) Flying-fox Camp Management Template 2019 (Department of Planning, Industry and Environment (DPIE) 2019)

2 Literature and data review

To understand the potential impacts of noise, light and dust on GHFF, peer-reviewed published articles and unpublished (grey literature) were reviewed. Various databases were searched (including Google Scholar, Web of Science, Wiley) using relevant search terms. Very few studies have directly addressed noise, light or dust impacts on pteropid species (insectivorous bats were more commonly studied). A broader scoping review was also undertaken on the impacts of noise, light and dust on other wildlife species, and where possible with a focus on species that may have similar physiological or ecological characteristics to GHFF. Other potential impacts are noted (Section 2.6) but have not been reviewed as they are outside the scope of this document.

2.1 Flying-fox ecology

To identify how noise, light or dust may affect flying-foxes, an understanding of flying-fox hearing, vision and olfactory senses is necessary, along with flying-fox behaviour, breeding season and nomadic patterns, camp use and occupancy. Supplementary information on flying-fox ecology and behaviour is provided in Appendix A.

2.2 Noise

Noise can be described as unwanted, harmful or inharmonious (discordant) sound (WSP 2020) or as the background sound that exists in any location or environment (Parris 2015). Noise can be continuous, intermittent, impulsive or low frequency (Noise News 2021). Sources of noise exhibit variance in frequency, amplitude, and spatial and temporal patterns (Blickley and Patricelli 2010). Frequency is the pitch of a sound and relates to the number of cycles it completes per second; this is measured in hertz (Hz). Humans with normal hearing can typically hear between 50 Hz to 20,000 Hz, or more generally written as 20 kilohertz (KHz). Amplitude is the volume or loudness of a sound and is measured in pressure or intensity and expressed as decibels (dB). Sound levels are commonly measured in dBA (decibel A – weighted sound levels) which describes the relative loudness of sounds in air perceived by humans (Parris 2015), however a range of other dB metrics may also be used. Comparative examples of noise levels are provided in Table 2.

Table 2 Comparative noise levels

Noise source	Decibel level	Decibel effect
Jet take-off (at 25 m)	150	Eardrum rupture
Aircraft carrier deck	140	n/a
Military jet take-off with afterburner at 50 ft	130	n/a
Thunderclap, chain saw	120	Painful 32 times as loud as 70 dB
Riveting machine, live rock music	110	Average human pain threshold
Outboard motor, lawn mower, garbage truck	100	n/a
Motorcycle	90	Likely damage in 8 hours of exposure
Garbage disposal	80	n/a
Vacuum cleaner	70	n/a
Conversation	60	n/a

Noise source	Decibel level	Decibel effect
Library	40	Lowest limit of ambient urban sound

n/a Not available.
Source: IAC acoustics 2021

2.2.1 Impacts of noise on wildlife

Increasingly, many species are being exposed to anthropogenic noise pollution (Kunc and Schmidt 2019). The impacts of noise on biodiversity have been widely studied with a focus on certain taxonomic groups (mammals, birds and fishes) and on particular noise sources (transportation and industrial) (Sordello et al. 2020). Anthropogenic noise pollution is known to have a range of impacts on wildlife. Noise sources and exposure levels vary greatly, but wildlife response to noise levels starting at 40dBA have been observed (Shannon et al. 2016).

Two of the most well studied effects of noise are behavioural and communication impacts. Animals may temporarily or permanently avoid areas affected by noise. Noise can hinder animal communication or social signals reducing mating success. Masking can occur when noise interferes with an animal's ability to hear a cue or signal, such as from an approaching predator (Berger-Tal et al. 2019). Animals may also change their vocal behaviour by changing the amplitude, frequency or temporal structure of their calls – this is known as the Lombard effect (Brumm and Zollinger 2011).

Physiological impacts have also been noted. Researchers have detected higher levels of stress hormones in animals that remain in noise-impacted areas, which may lead to reduced breeding success or weakened immune systems (Blickley et al. 2012). Fitness costs may occur due to the extra energy expended in avoiding noise or changing other behaviours such as increased amplitude of vocalisations (Francis and Barber 2013). Temporary or permanent hearing loss may also occur; singular loud noise events or repeated exposure to high noise levels can damage the inner ear which can impact on hearing ability. All species have hearing thresholds, which is the level at which a sound can be heard; changes to this threshold could result in reduced conspecific communication or awareness of predators or prey (Parris 2015).

Understanding how noise impacts on wildlife is challenging as species have different sensitivity to noise; this may also vary depending on factors such as life history and sex. Another confounding factor in studies is that noise is rarely isolated from other environmental changes, such as visual disturbance or habitat destruction. Animals may appear to become habituated to certain noises and noise levels, but research by Francis and Barber (2013) suggests that the presence of a species in a particular area does not necessarily indicate that it is not affected by noise.

Noise types and examples (TMR 2016; NoiseNews 2021)

- Continuous – factory equipment, engine noise, heating and ventilation systems, generators and pumps, idling machinery, vehicles or machinery (excavators, dozers, graders, trucks) and traffic
- Intermittent – train, aircraft, traffic, sirens, clapping and cheering, rock fall and tree fall
- Impulsive – demolition, construction, explosions/gun fire, fireworks, pylon-driving, metal falling on metal, air release, hammering, chipping

- Tonal – air compressor, grinding
- Low frequency – wind turbines, bass drum, heating and ventilation systems, machinery, transport and traffic, vibrator rolling

2.2.2 Potential impacts of noise on flying-foxes

Flying-fox hearing

Flying-fox hearing sensitivity and vocalisations are in similar range to that of human hearing (Calford et al. 1985). GHFF are able to hear sounds in the frequency range 2 to 54 kHz (Calford et al.1985). Flying-foxes appear most agitated by impulsive sound (seeTable3 for examples); excessively loud, sharp or sudden bursts that are fast or surprising in nature. Metal-on-metal noise is effective at disturbing flying-foxes during intentional camp dispersal (pers. com. J. Martin 2018; Ecosure pers. obs. 2015-2021). Vibration from machinery and subterranean work can also disturb flying-foxes in a camp (SEQ Catchments 2012).

Hearing is vital to conspecific communication between flying-fox individuals. A study of the vocal repertoire of flying foxes showed that they are capable of more than 25 individual sounds, which is matched only by primates (Nelson, 1964 in Markus and Blackshaw 2002). A study by Christesen and Nelson (2000) identified 5 distinct call types (Christesen and Nelson 2000 in Markus and Blackshaw 2002). For example, when female flying-foxes return to camps during the night and in the morning, it triggers a high-pitched, trilling, 'chirrup' location call (Nelson 1964) from pups to alert mothers to their whereabouts.

Flying-fox camps are notoriously loud (Eby and Lunney 2002 in Pearson and Clarke 2018). Even in a camp surrounded by heavy industry and rail infrastructure (Clyde camp, Sydney), the colony noise with the animals' own calls (57 dBA at 10 m) was louder than the surrounding environmental noise (51 dBA) at the site (Pearson and Clarke 2018). Pearson and Clarke (2018) suggest that the way GHFF species communicates (e.g. loud vocalising in close proximity to one another) could account for its tolerance of relatively high anthropogenic noise pollution levels in urban habitats.

High noise levels may affect GHFF communication behaviour. Cessation of vocalising due to anthropogenic noise has been termed the silentium effect, which has also been noted in marine mammals (e.g. whales and dolphins) and frogs (Pearson and Clarke 2018). During a noise study of a flying-fox camp near Sydney's Kingsford Smith Airport (Pearson and Clarke 2018), assessors documented cessation of calling by flying-foxes for up to 40 seconds when subjected to high amplitude noise from low overflying aircraft. This 'go quiet' behaviour, essentially the opposite to the Lombard effect, was observed when the aircraft noise exceeded colony noise by 100% (Pearson and Clarke 2018). The aircraft noises overlapped the lower frequency range (0.5 to 2.0 kHz) used by flying-foxes in their vocalisations and significantly exceeded the colony background noise measured before and after the aircraft noise (Pearson and Clarke 2018). Researchers considered whether the 'go quiet' effect was a response to the visual presence of the plane which may be perceived by flying-foxes as a predator, but concluded this was unlikely.

The masking effect of noise has not been directly studied for flying-foxes, however, flying-foxes have been observed to temporarily move away from construction noise to another part of the camp (Ecosure pers. obs. 2020 at Isle of Capri, Gold Coast; Section 2.6). These behaviours could affect energy expenditure (Bowles 1995). Much of the literature on noise disturbances on wildlife focuses on immediate aversive responses of animals, where a continuum of responses from mild aversion (flapping of wings) to more intense aversion such as longer movements or attacks on conspecifics, to long interruptions of normal behaviour such as panic-induced flying (Bowles 1995). Aversion to intense noise may result because an animal experiences auditory pain, but it is more likely to be the result of startling or fright (Bowles 1995). At certain levels of noise wild animals can become irritable, which can affect food intake, social interactions, or parenting. These effects might eventually result in population declines (Bowles 1995).

Limited noise monitoring has been carried out during some construction projects near flying-fox camps in NSW. The Balgowlah and Burdekin Park camps tolerated construction noise impacts around 74 dBA (SLR Consulting 2017 in WSP and Parsons Brinckerhoff 2017). When monitoring noise, baseline and background level are required to determine 'normal' ranges for that location. The type of noise along with the level, duration and frequency of any increases must be considered, with increased risk of disturbance associated with increasing levels of each factor.

2.3 Light

Just as clean air and unpolluted water and soil are considered vital for the wellbeing of many species, so too is natural darkness and natural light. Natural light functions as a stimulus that influences the behaviours and physiology of all organisms, and artificial lighting changes the length of natural photoperiods (Blackwell et al. 2015). Sources of artificial lighting include streetlight, spotlights, headlights, flashing beacons, traffic and skyglow at night. Lighting technology has changed the spectral content of artificial lighting from predominantly orange sodium-based lighting in the 1960s and 70s to broader wavelength lights such as the highly bright light-emitting diodes (LEDs). Light pollution is increasing at an annual rate of 6% worldwide (Holker et al. 2010).

2.3.1 Impacts of light on wildlife

Artificial light is known to have adverse impacts on many species. One of the most studied impacts is behavioural change, which has consequences for critical life stages such as nesting and migration. Animals may avoid breeding or feeding in certain areas which may put them at greater risk of predation or other disturbances. Birds and bats may be diverted from migratory routes or collide with infrastructure. Physiological changes in wildlife can also occur, such as delayed reproduction or increased stress hormone levels (DEE 2020).

Light exists as waves and photons (particles) that exist on a spectrum, but only a portion of the spectrum is visible to most animals. Light can be measured in lumens, which is the total amount of light emitted in all directions from a source, and lux or illuminance, which is the amount of light that falls on a surface per unit area. Using just these measurements to discern biological effects is often not adequate, as animals respond to the intensity of light hitting the photoreceptors in their eyes. Given that animals perceive light differently from humans, measuring in a biologically meaningful way is challenging (Blackwell et al. 2015).

2.3.2 Potential impacts of light on flying-foxes

Flying-fox vision

Flying-foxes have large, forward-facing eyes giving them binocular vision, while mirror-like retinas reflect and capture the limited available light (DES 2020c). Although primarily nocturnal, flying-foxes eyesight extend to bright light conditions (Muller et al. 2007) as demonstrated by their agile flight and intense social contact at the daytime camp. Visual tests done on the Indian flying-fox (*Pteropus giganteus*) found that the acuity of their vision in low light exceeded that of a human, but was not as high as a human's in bright light (Neuweiler 1962). Flying-foxes seem to have a visual ability that compares with the nocturnal and diurnal visual alertness of a cat, *Felis catus* (Graydon et al. 1986).

Flying-foxes are exposed to light pollution due to their nocturnal nature. Flying-foxes use illumination as a trigger for emergence – emergence time appears to be influenced by both natural and anthropogenic factors (Parsons 2011). Emergence from a camp can vary from approximately 30 minutes after sunset in summer, to nearly one hour after sunset in winter (Meade et al. 2019) however variations exist during overcast days or after severe weather. There was a possible effect observed from increased anthropogenic lighting over a flying-fox camp in tropical North Qld, with an apparent variation in flying-fox emergence time, correlated with increased activity from a nearby port (Parsons 2011). Earlier emergence associated with artificial lighting may increase energy expenditure and has the potential to interfere with rest / rearing at the camp.

Lewanzik and Voight (2014, 2017) found that street lighting altered frugivorous bat activity including abandoning traditional commuting routes or performing more explorative flights in the dark. Lewanzik and Voight (2014) suggest light pollution potentially deterred bats from reaching their preferred foraging habitat, whilst others propose that streetlights may be aiding in flying-fox navigation (Birt et al. 2000 in Geolink 2013).

Artificial light is known to adversely affect bat behaviour including reproduction and communication (DEE 2020; Stone et al. 2015; Patriarca and Debernardi 2010). However, as detailed in Appendix I – Bats (DAWE 2021b) of the National Light Pollution Guidelines for Wildlife (DEE 2020), the behaviour of frugivorous bats (such as flying-foxes) may not be impacted as much as insectivorous bats. The GHFF is a light-tolerant species based on their predicted behavioural response to artificial light (DAWE 2021b). They are known to camp in artificial light-drenched areas suggesting they are unlikely to be impacted from some level of artificial light, though formal research is yet to confirm light impacts on Australian frugivores and nectarivores (DAWE 2021b).

PROVolitans is a company that has designed a light specifically to deter flying-foxes from conflict locations (PROVolitans 2019). The light is designed to emit wavelengths that flying-foxes perceive as abnormal, based on the anatomical structure of their eyes. As the light is different to what a flying-fox would normally experience in a 24-hour cycle, it encourages them to move away from the light. A trial was conducted in 2018 in which PROVolitan lights were positioned above the canopy of a roost tree (attached to a cherry picker) for one night. According to PROVolitans (pers. comm. 2020), the trial yielded an 80% decrease in the number of flying-foxes roosting in the tree and flying-foxes avoided the tree the following morning. Flying-foxes were observed roosting 150 m away. While this light system has been specifically designed to deter flying-foxes, it highlights the potential for light to impact GHFF at their camps.

2.4 Dust

Airborne particles are defined as fumes, smokes, mists or dusts depending on the nature of the particle and its size (DEC 2011). Particulates can have a range of adverse consequences including mechanical effects, by which the inhalation of dust which may overload or irritate the respiratory system and facilitate infections, or immunosuppressive effects as high levels of dust, gases or micro-organisms in respiratory systems may lead to reduced resistance or allergies

(Hartung and Saleh 2007). The size of the particle is of critical importance as the smaller the particle, the deeper it can be deposited in the respiratory tract –very small particles can access alveoli in the lungs (Hartung and Saleh 2007).

Sources of dust include:

- wind-borne dust from cleared land or construction sites, remediation works on contaminated sites
- from stockpiles of coal, fertiliser, sand and mineral ore
- ripping, digging, or excavating
- mines and quarries
- road building
- cutting, grinding, jackhammering
- demolition
- blasting (SCARCS 2006).

Even dust from unpaved roads can impact human health, vegetation, and livestock (Aleadelat and Ksaibati 2017). The distance that road dust can travel is affected by the speed of vehicles, road surface, particle size, wind speed and direction, and the type and density of roadside vegetation (Farmer 1993; Spiess et al 2020).

Air quality can also be reduced by emissions from machinery and vehicles used for transportation. Emissions of pollutants include those from power stations, refineries and petrochemicals, chemical and fertiliser industries, metallurgical and other industrial plants, and municipal incineration (Manisalidis et al. 2020). Toxic dust comes in many forms from crystalline silica, beryllium, timber dust, alumina, textile dust and nanoparticles (SCARCS 2006). Particulates may also be contaminated with metals or chemicals from both focal and diffuse sources such as mining and processing sites, transport to processing sites, the agricultural sector that relies on phosphate fertilisers, as well as the burning of fossil fuels for energy. Mercury and cadmium are known to be released from coal-fired power plants (Peralta-Videa et al. 2009) and Australia is one of the largest producers of lead and other toxic metals (Pulscher et al. 2020).

2.4.1 Impacts of dust on wildlife

There is a paucity of studies on the impacts of dust on wildlife, but there are some studies on birds. Due to similarly high metabolic rates, birds are potentially a useful study parallel for understanding possible impacts of airborne pollution on flying-foxes. One study suggests that birds can be affected by air pollution through ingestion of fine particles into the liver and lungs due to their high metabolic rate and special respiratory system (Li et al. 2016). Navigation may also be impacted as this relies on visual and olfactory cues and could potentially be affected by reduced visibility or chemical interference. Shongqiu et al. (2016) suggest that pigeons homed faster when flying through highly polluted air, with one hypothesis being that they are striving to reduce exposure to pollutions and reduced visibility by moving through those areas as quickly as possible. Spiess et al. (2020) found that dust emissions from heavy traffic on rural roads did not influence the abundance of some bird species (e.g. blackbirds, kingbirds, shrikes). However, they stressed that the study species belonged to a group of birds highly acculturated to existing agricultural land use.

Dusts have diverse origins and different chemistries, some of which may be toxic (Farmer 1993). Thousands of birds, mainly nectar-feeding species (e.g. honeyeaters, wattle birds, yellow-throated miners; WA Legislative Assembly 2007) died in Esperance, Western Australia, from foraging on lead contaminated plants when lead carbonate dust was released during transport operations (Callan et al. 2012; DECWA 2007 in Pulscher et al. 2021).

Plant species may also be impacted by dust and other air pollutants which may have indirect impacts on wildlife if there is a decrease in their food plants and habitat quality (Lovich and Ennen 2011). Dust can have a physical or a chemical impact. Dust may physically smother plants and reduce photosynthesis and transpiration (Farmer 1993). Pollination activity has been shown to be reduced in areas impacted by dust which may limit seed production and fruit abundance (Farmer1993; Phillips et al. 2020). Dusts containing substances that are toxic or have different pH can cause a range of physiological impacts that reduce plant growth (Farmer 1993).

2.4.2 Potential impacts of dust on flying-foxes

Flying-fox olfactory senses

Frugivorous species such as flying-foxes are thought to be visually and olfactorily adapted for food location (Fleming 1988 in Oldfield 1996). Ratcliffe (1932) suggested that flying-foxes located their food solely by olfaction rather than visual cues, as bat-dispersed fruits and bat – pollinated flowers generally have strong odours (van der Pijl 1957). Over short distances flying-foxes can not only discriminate between different plant-derived odours, but they have different patterns of preference for odours (Oldfield 1996). As flying-foxes utilise food resources that are patchily distributed in space and time, it is essential for them to maximise their energy investment in foraging by having well developed senses for finding ripe fruit and nectar laden flowers. Fleming (1982) describes frugivorous bats as 'time minimisers' rather than 'energy maximisers' in their search for food (Oldfield 1996).

Pulscher et al. (2020) suggested flying-foxes are potential bioindicator species for environmental metal exposure due to their large range across diverse habitats. This study found a reduction of lead concentrations in flying-fox tissues compared with those sampled in 1993, due to the banning of lead-based paint in 1978 and lead-based petrol in 2002. Lead released into the Australian environment in the past persists predominately in the soil in large cities which can be resuspended in the air as dust and taken up in the edible portions of plants (Pulscher et al. 2020). The 2020 study also found higher concentrations of mercury in GHFF tissue compared with 1993, and higher concentrations of arsenic in black flying-fox (*Pteropus alecto*; BFF) tissue; possible sources of mercury could include emission from transportation, metal mining and refining industries and coal-fired power plant (National Pollutant Inventory 2020).

Pulscher et al. 2021 also found significantly higher concentrations of cadmium in the fur of the Christmas Island flying-fox (*Pteropus melanotus natalis*) compared to flying-foxes in mainland Australia, potentially a result of extensive phosphate mining on Christmas Island. A likely source of cadmium exposure for Christmas Island flying-foxes is through ingestion of food contaminated by airborne cadmium (fruit, leaves, and flowers) or during grooming. Heavy metal poisoning can lead to a range of health impacts, including organ dysfunction, metabolic disease, bone disease, reduced reproductive success (Pulscher et al. 2021) and death (WA Legislative Assembly 2007).

2.5 Summary of potential impacts on GHFF

A summary of potential impacts associated with noise, light and dust on GHFF at their camps, as discussed above, is shown in Table 3.

Table 3 Summary of potential impacts

Factor	Potential impacts	Impact category
Noise	• Avoidance of areas temporarily or permanently • Increase in stress behaviours (e.g. wing fanning, taking flight) • Changed timing, frequency or volume of vocalisations	Behavioural
	• Fitness consequences due to stress and increased energy in avoiding noisy areas and changing vocalisations • Reduced breeding success due to masking of conspecific vocalisations • Impaired hearing	Physiological
Light	• Avoidance of areas temporarily or permanently • Change in timing of roost departure/return	Behavioural
	• Fitness consequences due to increased energy in avoiding artificial lighting and reduced foraging time	Physiological
Dust	• Scent from food sources may be reduced requiring additional travel distance to find uncontaminated food sources	Behavioural
	• Fitness consequences due to increased energy expenditure sourcing food • Ingestion of toxic substances via food sources or grooming; respiratory issues	Physiological
	• Reduced habitat/food sources due to reduced plant growth and fruit production	Habitat

2.6 Other potential impacts

Causes of other similar potential impacts on a camp, but that are beyond the scope of this document, include:

- altered water flow, salinity, pollutants or sediment that may impact water quality for belly dipping, camp microclimate, or impact camp vegetation causing die off or tree fall
- proximity of buildings to a camp which could impede flight paths and cause overshadowing of vegetation affecting camp microclimate and vegetation composition.

2.7 Case studies

A total of 11 case studies are summarised in Table 4, with further detail in Appendix B. These provide examples of flying-fox response to unintentional disturbance (including noise, light and dust), and have been used to inform Section 3. Rigorous monitoring during similar future activities is required to provide additional information and ensure impact assessment and mitigation is evidence-based. Case studies 1 to 5 in Table 4 are camps in urban areas. These urban camps generally showed higher levels of tolerance compared with case studies 7 to 11 in less urban areas, likely to be due to being habituated to anthropogenic activity (along with project mitigation measures tailored to flying-foxes, shorter duration and lower intensities of the projects). Levels of disturbance are outlined in Section 3.3.2.

The urban camp in case study 6 is considered an outlier because while the camp was not abandoned during the study period, observations showed considerable impacts resulting in high rates of mortality and pup abandonment. While no definitive causal link could be shown between construction and increasing rates of mortality/abandonment, the consensus amongst flying-fox researchers, local carers, and people monitoring the camp is that mortality/abandonment was related to construction (particularly pile-driving and overhead cranes during the rearing season), and effects were compounded by cumulative impacts of removing trees across multiple projects. See Appendix B for further detail.

Eby (2013; in SKM 2017) summarised the conditions and outcomes of 5 of the construction projects (case studies 7 to 11) near the flying-fox camps:

> Four of the camp sites were abandoned during construction and not re-established; and one campsite was abandoned but re-established 20 years later. It should be noted that whilst substantial construction activities were occurring around 240 m from the Kurnell camp, the timing of camp abandonment at that site was additionally associated with drawdown of surface waters during severe drought conditions. As such it is not conclusive that the abandonment of the Kurnell camp could be attributed to adjacent construction activities. In addition, the temporary camp that formed near the township of Tarcutta, NSW was established during a uniquely long and widespread food shortage for flying-foxes in southeast Australia. The animals departed the site at a time when other temporary camps in the regional area also emptied. This also coincided with pile driving during construction of a bridge 250 m from the camp. It is therefore not clear whether departure from the site was associated with the pile driving.

Table 4 Summary of 11 case studies of camps that were adjacent to construction or anthropogenic disturbance

Case study	Stimuli	Camp (BFF, GHFF, LRFF, SFF)	Project/proponent	Activities	Project timeframe	Approximate distance camp to works	FF behavioural outcomes	Assumed level of habituation related to location	Tolerance demonstrated / outcome
1	Noise	Parramatta Park camp, NSW (GHFF)	Parramatta Light Rail	Transport for NSW Construction activities included demolition, rock and concrete breaking, tree removal and piling.	2019-2023	Within 300 m Some bridge piling ~ 100 m Maintenance (mowing) in Parramatta Park is less than 20 m from parts of the camp.	High noise construction activities had negligible observable impact on the GHFF camp during monitoring period. Flying-foxes did respond (e.g. lifting) to lawn mowing (not project related) for a short period of time.	High – Habituated to frequent park events and concerts, maintenance within 100 m, and other construction recently occurring in the local area (e.g. Western Sydney Stadium demolition in 2017 and re-build completed early 2019 {within 250 m of the camp}). Flying-foxes have consistently continued to use the camp to date.	Tolerance high; low impacts. Weekly disturbance from maintenance actions (particularly mower) results in short term behavioural response but flying-foxes settle quickly.
2	Noise, light	Commonwealth Park camp, ACT (GHFF)	Camp management and monitoring, National Capital Authority	Park maintenance including chain saws, mowers, mulchers, and events such as concerts, cannon fire, jet fly over.	Events and maintenance occur all year round	Between 0 and 200 m from camp.	Flying-foxes were able to settle within around 30 minutes of a disturbance activity or event. Flying-foxes remained at camp with some short-term behavioural responses.	High – Located in urban park and habituated to weekly park maintenance, regular concerts and events during the day and night.	Tolerance high; no impacts.
3	Noise, vibration	Remembrance Drive camp, Gold Coast, Qld (BFF)	Isle of Capri Bridge duplication City of Gold Coast and Georgiou	Bridge piling general trucks noise and intermittent construction	4 months	100 to 300 m from camp.	Showed no reaction to bridge piling works, approximately 30 m from camp extent during breeding and rearing season. On one day of monitoring, flying-foxes moved to a section of the camp 50 m further away from construction activity.	High –Located in high traffic urban area, habituated to road and water traffic, maintenance of nearby residents. Camp slightly buffered from works by 2 m high dirt stockpile.	Tolerance very high; no observed impacts.
4	Noise, vibration	Lions Head camp, Miami, Qld (BFF, GHFF)	Slope remediation works, City of Gold Coast	Chipper, rock breaking and loading, tree removal, rock stabilisation.	6 months	50 to 100 m from camp.	Flying-foxes occasionally flighty but mainly continued to rest during works. Located in urban area within 100 m from Gold Coast Highway.	High – Located in urban park with high foot traffic nearby, vehicle turning area and parking, nearby residences and cafes.	Tolerance high; low impacts.
5	Noise, tree removal, light, dust	Palm Beach camp and Currumbin camp, Qld (BFF)	Pacific Motorway Varsity to Tugun upgrade Transport and Main Roads and Seymour Whyte	Road construction, early works, tree clearing (night works), mobile plant, excavators, trucks	2020-2023	Over 200 m from camp	Flying-foxes remained in camp while tree removal occurred outside 100 m buffer area. Tree clearing later continued into roost vegetation and flying-foxes have remained at both locations to date.	High – Located in road verge immediately adjacent to 4 lane motorway and residences.	Tolerance high; low impacts.
6	Noise, tree removal, cranes, pile driving	Cairns, Qld (SFF)	Tree removal and construction of hotel, various proponents	Cranes, piling	Tree trimming 2014-2017 Hotel construction 2016-2017	25 to 200 m from camp	Camp remained in situ but with high pup mortality and abandonment rates which seemed to increase with increasing construction activities, considered a result of cumulative impacts of multiple developments, tree removal. Negative response to overhead cranes and piling recorded by carers on site.	High – located in urban centre with high vehicle and foot traffic.	Tolerance low – moderate; high impacts
7	Noise, dust, vibration	Kempsey Crescent Head, NSW (GHFF)	Pacific Highway Kempsey bypass	Crushing and screening facility, bridge piling	2010-2013	200 m from crushing plant 500 m from bridge piling.	Colony present for first 2 years then abandoned.	Low – Located in a natural environment with only low density rural residential lots in the vicinity.	Tolerance low; camp abandoned. New camp site established at Rudders Park, 2 km away.
8	Noise, dust	Moorland, NSW (GHFF)	Pacific Highway Moorland to Herons Creek upgrade	Widen to 4 lane dual carriageway	2007-2009	Some camp vegetation removed.	Camp abandoned	Unknown	Tolerance low; camp abandoned. New camp site Lansdowne State Forest 7 km away.
9	Vibration	Kurnell, NSW (GHFF)	Sydney Desalination Plant	Construction of extensive plant; 5 km pipeline; tunnelling; trenching	2007-2010	240 m to above ground works, 450 m to below ground works.	Camp abandoned during construction (but coincided with changed water regime)	Unknown but likely low, camp location is surrounded by desalination plant so likely occurred in a natural area.	Tolerance unknown; camp abandoned but unconfirmed cause. New camp site established at Kareela 10 km away.
10	Noise, light, dust	Slacks Creek, Qld (BFF, GHFF)	Southeast Freeway	Construct dual carriageway, interchange, bridge.	Unknown (Southeast Freeway	175 m to highway, 200 m to bridge	Camp abandoned during construction re-established after 20 years.	Unknown	Tolerance unknown; camp abandoned but unknown cause.

Case study	Stimuli	Camp (BFF, GHFF, LRFF, SFF)	Project/proponent	Activities	Project timeframe	Approximate distance camp to works	FF behavioural outcomes	Assumed level of habituation related to location	Tolerance demonstrated / outcome
					completed 1985)				
11	Noise	Tarcutta, NSW (considered a temporary site due to food shortages) (GHFF)	Hume Highway Tarcutta bypass	Construct 4 lane dual carriageway; bridge.	2009-2011	230 m to highway, 250 m to bridge.	Camp abandoned during construction.	Unknown but likely low/moderate, close to Tarcutta and a main road to the south, but area to the north of the camp previously natural area/farmland.	Tolerance unknown; camp abandoned but possibly a temporary camp that would have abandoned naturally.
12	Noise, vibration, dust	Campbelltown, NSW (GHFF)	Access road	Construct 2 lane road; bridge piling.	Unknown	80 m to road, 300 m to bridge.	Camp remained through construction.	Moderate – high, located in urban area with industrial land use nearby, freeway and train line nearby, but camp somewhat buffered with vegetation and cleared area.	Tolerance moderate-high; impacts low.

BFF Black Flying-fox. **GHFF** Grey-headed Flying-fox. **LRFF** Little red flying-fox (*P. scapulatus*). **SFF** Spectacled flying-fox (*P. conspicillatus*).
Note: Further information on case studies one to 6 can be found in Appendix B and 7 to 12 in SKM (2017).

3 Identifying impacts of noise, light and dust

This section provides advice on how to identify the potential impacts of noise, light and dust on the GHFF.

Please note this document provides supporting information only, and only relates to noise, light and dust impacts. Assessment of potential impacts on the GHFF must be informed by the statutory GHFF Recovery Plan and Significant Impact Guidelines 1.1 – Matters of National Environmental Significance, which also explain the concept of a 'significant impact'.

3.1 Identifying the camp and habitat

3.1.1 Status of the camp, and condition and quality of camp habitat

The first step is to determine if the camp is a nationally important camp under the EPBC Act (see Section 1.4).

To determine if camp vegetation will be impacted, it is necessary to identify camp composition, condition and structure. If the camp (or surrounds) is comprised of foraging trees, there is potential for heavy metals / toxic particles (for example in a mining context) to coat flowers and fruit and be ingested by flying-foxes. The condition and structure of roost trees may buffer noise, light or dust impacts (e.g. a complex vegetative structure increases buffering). Furthermore, the size and structure of the camp should be assessed to determine whether there is suitable adjoining vegetation to enable flying-foxes to temporarily move away horizontally or vertically from disturbance if needed. The condition of vegetation may assist the camp's ability to withstand disturbance over time (e.g. Commonwealth Park camp, ACT, experiences regular tree fall due to failing health from changed watering regimes and root damage. Ongoing tree fall may reduce the size or available roosting space in the camp and therefore reduce the ability of flying-foxes to avoid or adapt to regular anthropogenic disturbance).

3.1.2 Establishing baseline behaviour

It is important to establish baseline behaviour of GHFF individuals and the colony to ascertain whether a change has occurred due to a disturbance or action. Normal flying-fox behaviour includes nomadic movements in relation to resource availability or breeding (see Appendix A) whereas unusual changes to camp occupation may include inadvertent dispersal or splintering or camp abandonment. Reference camps can act as control sites to provide a benchmark of typical flying-fox behaviour and trends in the area. Reference camps will ideally be in the same general locality, with similar historical patterns of occupancy. Baseline data allows establishment of:

- patterns of occupation (population size, frequency: continuously, annually, irregularly or rarely (Roberts 2005))
- demographic composition (sex and age class)
- species composition
- key behaviours (including reproductive status; is it a maternity camp?)

- area of occupancy (camp size, location and maximum known extent of roosting flying-foxes).

3.2 Identifying the likelihood of impacts

3.2.1 Predicting the likely level of tolerance of the camp to noise, light and dust

Flying-foxes, like all wildlife, can habituate to some things over time that may initially elicit a response. For example, when strobes and lights are used to intentionally deter flying-foxes, they can be effective initially, but over time they become less effective through habituation (DPIF n.d.; Ecosure pers. obs. 2015-2020). A trial in 1992 with a strobe light of high intensity yielded a very slight reaction to the lights and did not deter flying-foxes from roosting (reported in van der Ree and North 2009).

A camp's tolerance to noise, light and human activity is highly variable and appears to be correlated with the location's regular level and occurrence of these impacts. Urban camps (e.g. Clyde and Parramatta Park [Sydney], Isle of Capri and Lions Head [Gold Coast], and Commonwealth Park [ACT]) have demonstrated a high level of tolerance to anthropogenic noise, likely because they are habituated to traffic, construction and concerts (Table 4). Conversely, small disturbance, such as high visibility clothing, sound of twigs breaking underfoot or vehicles, cause flying-foxes in some remote camps to present a stress or a version response (pers. Obs. Ecosure 2010-2021). Bowles (1995) attests to this observation that

> the proportion of mammals and birds responding with flight varies greatly depending on previous experience, season, group size, age and sex composition, on-going activity, motivational state, reproductive condition, terrain, weather, temperament, and other natural factors.

Both humans and laboratory mammals can tolerate very high noise levels during sleep after they have adapted behaviourally and physiologically; a process that can take several months (Suter1992 in Bowles 1995). Understanding habituation or flying-fox tolerance to stimuli relies on the ability of an observer to understand normal flying-fox behaviours versus stress induced behaviours. Predicted tolerance, or intolerance, of a camp to stimuli based on normal exposure to those stimuli at that location should be considered when assessing the likelihood of significant impacts.

3.2.2 Proximity of action to camp

The minimum distance of an action or activity to the flying-fox camp (considering recent camp extents and maximum known footprint) should be identified to see if sufficient buffers exist or whether additional mitigation is required. The location of the proposed action/s or activity (e.g. project extent overlay) in relation to the flying-fox camp extents can be identified by spatial analysis and illustrated on a map.

Based on case studies in Australia (Eby 2013; Ecosure 2019, [see Appendix B]) and noise modelling near flying-fox camps (Isle of Capri case study Appendix B), 300 m is recommended as a minimum buffer distance to avoid impacts to a camp, noting that some activities require greater distances, and considering the limitations of existing data and the need for further monitoring and assessment. If work is required within 300 m, the risk of impact is higher and additional controls may be required.

3.2.3 Timing of actions

The nocturnal nature of flying-foxes means actions are most likely to impact a camp during the day while they are resting. However, actions that are scheduled to occur at night during the crèching period could also affect young flying-foxes at the camp.

Table 5 shows the indicative breeding cycle of the GHFF and associated level of potential disturbance, where likelihood of disturbance is categorised into low, moderate or high likelihood of disturbance. Seasonally, spring to summer is the highest disturbance period in the GHFF breeding cycle.

Table 6 is an example risk matrix used for the Parramatta Light Rail project to assist identifying high disturbance periods. Proponents may want to schedule each activity in a similar style to identify and avoid high disturbance periods.

Table 5 Critical breeding period

Month	GHFF breeding	Likelihood of disturbance to FF
January	• Crèching (young left at camp) • Lactation	High
February	• Crèching (young left at camp) • Lactation	High
March	• Peak conception • Lactation	Moderate
April	• Peak conception • Lactation	Low
May	n/a	Low
June	n/a	Low
July	n/a	Low
August	• Final trimester	Moderate
September	• Final trimester	Moderate
October	• Peak birthing (crèching 3 to 4 weeks from birthing)	High
November	• Crèching (young left at camp) • Lactation	High
December	• Crèching (young left at camp) • Lactation	High

n/a Not applicable.
Note: This breeding period is indicative only and regular monitoring is critical to ensure pregnant females and/or dependent young are not impacted.

Table 6 Example risk matrix of day and night works inside 300 m buffer, by month

Month	Day works	Night works
January	Moderate risk	High risk
February	Moderate risk	Moderate risk
March	Low risk	Low risk
April	Low risk	Low risk

Month	Day works	Night works
May	Low risk	Low risk
June	Low risk	Low risk
July	Low risk	Low risk
August	Low risk	Low risk
September	High risk	Moderate risk
October	High risk	Moderate risk
November	High risk	High risk
December	High risk	High risk

Note: Low risk – dependent young unlikely to be present/impacted. Moderate risk – dependent young likely to be present and potentially impacted. High risk – if present, young very likely to be present and potentially impacted. Works to avoid these periods. If avoidance is not possible mitigation measures and frequent monitoring are likely to be required.
Source: Ecosure 2019

3.2.4 Source and nature of impacts

Proponents should identify activities and potential impacts over the lifespan of a project to inform the department's assessment.

The project site layout and maximum camp extent should be illustrated on a map. Once activities that may cause impacts are identified, the next step is to ascertain the scale and magnitude of those impacts. Modelling the spatial extent of potential impacts will help to determine magnitude, and at a minimum, should be completed by proponents for any action proposed within 300 m of a GHFF camp.

As with environmental impact assessment in general, there are often uncertainties and problems when assessing direct, indirect and cumulative impacts and impact interactions. Any assumptions used in the proponent's proposal and the department's assessment should therefore be documented.

3.2.5 Potential for cumulative impacts

Overlay mapping is a good method for identifying the spatial distribution of impacts and can assist in identifying where cumulative impacts occur.

Impacts from an action may be exacerbated by:

- concurrent environmental events that flying-foxes are susceptible to, such as heat stress events or extreme weather events that lead to food shortages
- other actions planned in the area (e.g. a construction project planned in the area) that may cause disturbance.

The proponent should document evidence that the potential to contribute to cumulative impacts has been sufficiently investigated and considered.

Where there is a high potential for cumulative impacts, the action should be referred to allow the department to properly assess the risk and condition appropriate measures to avoid/mitigate significant impacts.

3.3 Effects of impacts on GHFF

Once a potential impact is identified, the level of that impact on flying-fox behaviour, welfare and conservation needs to be determined. The effects of impacts could be immediate and obvious (acute) or experienced by the camp over a longer period (chronic), with impacts at both the individual and population level. Signs of stress in flying-foxes should be understood by assessors monitoring flying-fox camps before, during or after actions have occurred.

Some behavioural changes will be harder to observe in the short term however may have an impact on the colony over time. These changes include:

- communication interference – social, courtship and mating, parental care
- sleep disturbance
- stress-related illness or increases to psychological stress or increase disease susceptibility.

3.3.1 Impacts to pregnant females and crèching young

Reduced breeding success can be associated with disturbance from works that occur in the birthing and lactation season. Flying-foxes are known to abort foetuses and birth prematurely in the wild in response to environmental stress (McIlwee and Martin 2002). Mass abandoning of young has been observed at several camps in Queensland and NSW, particularly in summer.

3.3.2 Temporary or permanent camp abandonment

Disturbance at or adjacent to flying-fox camps may result in:

- diurnal lifting
- diurnal fly out
- reduced occupancy
- flying-foxes splintering to nearby vegetation or neighbouring properties
- camp abandonment.

Impacts may range from short-term, or temporary changes (e.g. lifting occurring for minutes; or the camp being abandoned for a short period before re-establishing), to long-term, or permanent changes, resulting in permanent abandonment.

4 Self-assessing and referring an action

The Significant Impact Guidelines outline a 'self-assessment' process to assist proponents in deciding whether referral to the Minister is required. The information presented above (summarised in Table 7) and in the statutory documents and policy statements for the species should be considered when undertaking this self-assessment process.

Table 7 Factors likely to influence the significance of impacts of actions on the GHFF

Category	Factor	Considerations
Flying-fox-specific	Time of year disturbance will occur	• Will the activity occur during medium /high-risk periods in the GHFF breeding cycle? • Can very disruptive work be avoided in high-risk periods? • For projects with long periods of disruptive works, can these commence in a low-risk period to allow flying-foxes to find an alternative site if required?
	Importance of camp	• Does it meet criteria to be considered nationally important? • What is the historic frequency and duration of occupancy? • Is it a GHFF maternity camp? • Could it be important for accessing critical foraging habitat, for example, is there an abundance of winter foraging habitat in the 10-20 km surrounds?
	Alternative camp habitat	• Is there alternative camp habitat equivalent in nature available in the local area (e.g. known GHFF camp occupied in recent years by similar numbers at similar times of the year)? If so, does this camp(s) have capacity to accept GHFF if they are displaced?
	Size of patch	• Are these areas suitable as camp habitat (ideally confirmed by previous roosting records, or otherwise habitat that meets known camp characteristics)?
	Likely tolerance to disturbance	• Is it an urban camp with high tolerance to disturbance, or, a camp in a natural area that is unlikely habituated to anthropogenic disturbance?
	Cumulative impacts	• Are there other population stressors that increase the risk of cumulative impacts? E.g. drought.
	Buffers	• Is there vegetation or other buffers between the camp and work area that may reduce visual/noise/light impacts?
Works-specific	Proximity to camp	• Considering the core camp area, recent extents across seasons, and combined maximum footprint (sum of all known extents), are works < or > 300 m?
	Type and level of disturbance that may cause impact(s)	• Are impacts: – noise/vibration: high impact such as high frequency noise (e.g. cutting steel), impulsive (e.g. rock breaking, bridge piling) – light – dust – other – multiple resulting in cumulative project impacts.

	Frequency/spatial extent	• What is the frequency/spatial extent of impacts?
	Daily works program and intervals between disturbance	• Does disturbance result in flight occurring sporadically? e.g. once per week) to regularly (multiple times per day).
	Duration/longevity of impacts	• What is the expected duration of impacts / how permanent is the change likely to be (assessed at the broadest scope of the project)?
	Footprint of work	• What is the footprint of work? E.g. one side of camp only or on all sides.
	Habituation	• Is there scope to gradually habituate flying-foxes to disturbance? E.g. starting work 300 m+ away and gradually moving towards the camp.

5 Monitoring and avoidance/mitigation measures

This section provides information on management and mitigation measures which may avoid or reduce the likelihood of significant impacts on the GHFF. Any avoidance or mitigation measure you plan on taking should be described in your referral documents submitted to the department.

5.1 Baseline monitoring

Monitoring ensures that survey data undertaken by environmental experts can be provided to the department as baseline data. This is an important consideration in a proponent's referral.

Additional longer-term monitoring may be required to provide sufficient information on attributes in Section 3.1 to allow an accurate assessment of potential impacts and inform potential avoidance and mitigation measures.

Baseline data is critical to evaluate the effectiveness of impact avoidance measures, identify natural flying-fox patterns or movements (which may otherwise be misinterpreted as impacts), and inform future actions.

5.2 Monitoring during and after an action

Once your action has been referred you may be required to undertake further monitoring. Each project is assessed on a case-by-case basis and the department will work with you to determine monitoring requirements. Common monitoring requirements are described below.

Frequency of monitoring during an action should be:

- immediately prior to potentially disturbing action
- during action (duration of monitoring required to be determined by a suitably qualified expert)
- immediately following each action (at least until flying-fox behaviour returns to normal).

This monitoring should be temporally paired with monitoring stimuli both at the source and at the receiving site (i.e. the camp). Flying-fox responses to different types/intensity of disturbance can then be used to determine tolerance thresholds (which vary between camps as discussed in Section 3). This information can be used to identify when additional controls may be required to avoid a greater impact (e.g. camp abandonment).

Continued monitoring by proponents and reporting to the department will fill current knowledge gaps and allow guidelines such as these to be refined and generally contribute to improved understanding of impacts to the GHFF and the extent to which they need to be managed.

Each monitoring event should record the number of flying-foxes present, approximate sex ratio, health condition, breeding activity and approximate age of young (if present).

Table 8 provides examples of signs of stress and what to look for when monitoring flying-fox behaviour.

Table 8 Signs of major disturbance/stress in flying-foxes

Potential impact	Signs
Major disturbance	• In flight for more than 5 minutes / leaving the camp • Flying-fox numbers reduce • Flying-fox colony splinters to nearby vegetation, neighbouring properties, multiple locations, new locations • Camp abandonment
Stress/fatigue	• Panting • Saliva spreading • Located on or within 2 m of the ground • Unusual vocalisations • Low flying • Laboured flight
Injury/death	• A flying-fox has been killed, injured, or found on the ground (including aborted foetuses) because of an action
Impacts to pregnant females and Crèching young	• Aborted foetuses, premature births • Abandoning crèched young en masse

5.2.1 Potential monitoring and management measures

The following are examples of monitoring and management measures. These should be used to inform adaptive management practices.

- monthly monitoring at least to assess changes (or no change) to camp behaviour and occupancy
- regular monitoring by a suitably qualified expert to identify changes in behaviour (at least weekly or more frequent as determined by suitably qualified expert)
- report to regulator immediately any identified changes in normal camp behaviour
- maintain a register to record details of monitoring and implement additional impact avoidance/mitigation measures if required
- site manager to review proposed activities and consider and implement alternative (less disruptive) methods.

5.3 Potential avoidance and mitigation measures

The following are examples of avoidance and mitigation measures. It is the proponent's responsibility to prove the effectiveness of these measures.

5.3.1 General mitigation and avoidance measures

- non-critical activities could be scheduled if or when the camp is naturally empty
- avoid highly disruptive activities during critical times of the breeding season or during fly-in (from nightly foraging) or fly-out (emergence)

- set up exclusion zones to avoid project activities approaching camp boundaries unnecessarily
- on days predicted to be >38°C, avoid works or consult with suitably qualified expert
- provide respite at least one day per week (e.g. Sunday) for activities audible at the camp to allow flying-foxes to rest
- if signs of major disturbance / stress are observed (Table 8), cease work in that area for at least 2 hours, adapt methods to reduce impacts in consultation with a suitably qualified expert and increase monitoring. If signs of stress are observed with works recommencing, cease activity in the area and contact regulator
- for each new activity (e.g. new scope of work or significant change in methodology) or a substantial reduction in the distance to the GHFF camp from a previously assessed activity, suitably qualified expert to monitor the camp
- record monitoring details in a register and provide to the regulator to determine the need for additional mitigation measures, allow the program to be evaluated and inform future programs.
- for each new activity (e.g. new scope of work) provide a copy of an Environmental Work Method Statement to suitably qualified expert for review and carry out additional control measures as determined by the suitably qualified expert.

5.3.2 Noise

Noise management options to avoid impacts on camps:

- ensure all plant and equipment is maintained to Australian Standards to minimise noise generation
- noise sources predictable (e.g. vehicles to remain on roadways)
- undertake work sequentially to facilitate gradual habituation of animals to noise, beginning the furthest distance where possible
- limit the duty cycle and duration of noise to allow recovery between exposures including respite at least one day per week (e.g. Sunday), for activities audible at the camp
- where possible, position plant and equipment further away from the camp and shield noise at the source
- consider quieter methods; avoid impulsive or high frequency noise (e.g. metal on metal) where practicable
- limit cumulative exposure to noise to protect animal hearing.

5.3.3 Light

Light management options specific to bats (DAWE unpublished):

- avoid adding artificial light to previously unlit areas
- avoid artificial light directed towards camp or that spills into camps
- direct artificial light downwards and/or shield luminaries near foraging areas and commuting corridors

- maintain connected dark corridors between camps, water sources and foraging area
- prevent indoor artificial lighting reaching the outdoor environment
- avoid using high intensity artificial light or unnecessary artificial light
- use luminaires with spectral content appropriate for the species present
- lighting should be directed and designed to minimise light spill into the ecologically sensitive areas
- ensure provision of dark areas within a camp, particularly at crèche trees.

5.3.4 Dust

Dust management options to avoid impacts on camps:

- adopt methods that minimise dust production
- treat dust at point of generation and transmission path
- place a physical barrier between dust generating task and camp
- suppress dust by using water sprays on stockpiles or roads
- seal gravel roads or maintain ground conditions
- cover conveyors and loads
- use wet cutting methods
- modify blasting programs to suit wind conditions
- limit the duration and magnitude of exposure to dust.

5.3.5 Contingency planning

If flying-foxes leave the camp during the day or appear in undesirable locations, or are injured or killed, contingency plans will need to be implemented to ensure both flying-fox and community health and safety. Site-specific contingency planning should be informed by a suitably qualified expert on flying-fox ecology and behaviour, but may include:

- adopting additional avoidance or mitigation measures (outlined above)
- modifying work location, intensity and/or schedule to allow flying-foxes more time to habituate to disturbance
- nudging flying-foxes to suitable locations (e.g. back to the camp if splintering has occurred or to nearby habitat further from stimuli).

As with any type of wildlife management, there must always be scope for flexibility to allow adaptive management based on monitoring results.

6 Conclusion

This document was developed to provide information on the impacts of noise, light and dust on the GHFF. It should be used to complement existing Commonwealth guidelines to assist the department and project proponents to determine potential impacts on GHFF.

There is limited specific data available to assess the severity and significance of impacts of noise, light and dust on flying-foxes and flying-fox camps. The Australian case studies that were investigated suggest that camps located in urban areas appear to exhibit higher level of tolerance to a range of anthropogenic disturbance. These camps, with appropriate impact avoidance measures, are less likely to be significantly impacted than those in non-urban areas. Further research would allow more accurate predictions of impacts on GHFF and help determine the effectiveness of mitigation/avoidance measures.

Appendix A: Flying-fox ecology and behaviour

Flying-fox ecology

Flying-foxes feed on the nectar and pollen of a range of species of *Myrtaceae* and *Proteaceae* including eucalypts (including *Corymbia* species), melaleucas, banksias and grevilleas, supplementing their diet with fruits (native, orchard and ornamental) (Eby and Law 2008, Eby et al. 2019). Flying-foxes, along with some birds, make a unique contribution to ecosystem health through their ability to move seeds and pollen over long distances (Southerton et al. 2004). This contributes directly to the reproduction, regeneration and viability of forest ecosystems (DAWE 2020).

GHFF and BFF show a high level of fidelity to camp sites, returning year after year to the same site. Flying-foxes are long-lived animals (15-20 years) (McIlwee and Martin 2002), which may contribute to their high degree of site fidelity (DES 2020d).

Flying-foxes appear to be roosting and foraging in urban areas more frequently. This is thought to be a result of year-round food availability and loss of other foraging resources but also demonstrates an increased tolerability of flying-foxes to anthropogenic activities or disturbance. During a study of national flying-fox camp occupation, almost three quarters of the 310 active GHFF camps (72%) were located in urban areas, 22% on agricultural land and only 4% in protected areas (Timmiss 2017). Furthermore, the number of camps increased with increasing human population densities (up to ~4,000 people per km2) (Timmiss 2017).

Breeding season

Peak conception for GHFF occurs around March to April/May (Table 9); this mating season represents the period of peak camp occupancy (Markus 2002). Young (usually a single pup) are born 6 months later from September to November (Churchill 2008). Young are suckled and carried by the mother until approximately 4 weeks of age (Markus and Blackshaw 2002). At this time, they are left at the camp during the night in a crèche until they begin foraging with their mother in January and February (Churchill 2008) and are usually weaned by 6 months of age around March.

Table 9 Indicative GHFF breeding cycle

Month	Breeding stage	Lactation
January	Crèching (young left at camp)	Yes
February	Crèching (young left at camp)	Yes
March	Peak conception	Yes
April	Peak conception	n/a
May	n/a	n/a
June	n/a	n/a
July	n/a	n/a

August	Final trimester	n/a
September	Peak birthing (crèching 3 to 4 weeks from birthing)	Yes
October	Peak birthing (crèching 3 to 4 weeks from birthing)	Yes
November	Peak birthing (crèching 3 to 4 weeks from birthing)	Yes
December	Crèching (young left at camp)	Yes

n/a Not applicable

Nomadism

Flying-foxes are highly nomadic, moving across their range between a network of camps throughout the east coast of Australia (546 known camps sites for GHFF across 85 LGAs; Welbergen et al. 2020a). Camps may be occupied continuously, annually, irregularly or rarely (Roberts 2005), and numbers can fluctuate significantly on a daily (up to 17% daily colony turnover; Welbergen et al. 2020a) and seasonal basis. Although camps may become vacant periodically, once flying-foxes have utilised a site, the habitat is permanently protected under legislation.

Empty camp – natural or unnatural?

It is important to be able to decipher between normal flying fox nomadic behaviour, their responses to resource availability or seasonal movements for breeding, as opposed to inadvertent dispersal or abandonment of a camp due to impacts.

The significance of temporary abandonment or permanent abandonment of a camp will likely depend on whether:

- the camp is nationally important
- the camp is a maternity site
- abandonment occurs during the breeding season.
- whether suitable roosting alternative exist near food resources

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- whether suitable roosting alternative exist near food resources.

Cumulative impacts

Impacts to the GHFF may be greater if an action is proposed during a time of population stress (e.g. food shortage) or during extreme weather (which might exacerbate heat events). Flying-foxes are extremely vulnerable to temperatures above 38°C and have suffered widespread mass mortality when temperatures reach 42°C (Welbergen et al. 2008, Collins et al. 2019, Bishop et al. 2019). Individuals may exhibit certain behaviours when suffering heat stress including lifting/fanning, panting, licking their wrists/wing membranes and lowering themselves into midstory vegetation to reduce direct exposure to the sun (DPIE 2015).

Appendix B: Case studies

This appendix provides additional information on case studies summarised in Section 2.7 and should be read with referral to Table 4.

Case Study 1 – Parramatta Park camp, NSW

Parramatta Light Rail Project, Transport for New South Wales

The Parramatta camp is a nationally important GHFF camp located on the Parramatta River within Parramatta Park. The Park is located within metropolitan Sydney and there are high levels of human activity associated with recreational park use, park maintenance, and regular public events (such as concerts).

As the *Parramatta light rail project* (PLR project) was deemed to be State Significant Infrastructure, there were Conditions of Approval to minimise potential impacts to the Parramatta Park camp, including: Monitoring must commence at least 12 months before the commencement of construction within 300 m. To meet these conditions, Transport for New South Wales (TfNSW) developed a *Grey-headed flying-fox construction monitoring program* (the Program) for the PLR project (Ecosure 2019).

The Program included measures to avoid construction impacts, and implemented requirements for monitoring during construction works, especially for activities most likely to cause disturbance (e.g. pile driving, and construction within 300 m of the Parramatta camp) and during high risk periods (e.g. the flying-fox rearing season). The Program also included a condition that if flying-foxes continued to be disturbed after 10 minutes, work should cease and the regulator be informed to determine the most appropriate way forward.

Narla Environmental (2020) monitored the Parramatta camp during construction activities occurring within 300 m of the camp (such as demolition, rock breaking, concrete breaking, tree removal and piling). GHFF behaviour was monitored at the start of each activity, for a period of 30 minutes. Flying-foxes were observed briefly moving away from construction disturbance, however, they stayed within the existing camp boundary. This movement was considered to be low impact.

Prior to the PLR project, other significant construction activities occurred in close proximity to the Parramatta Park camp non-related to the project; these included the Western Sydney Stadium re-development (within 250 m of the camp) and the Parramatta Leagues Club multilevel car park (within 80 m of the camp). With regard to the Parramatta Leagues Club car park, the regulator deemed the applicant's technical report for DA 310/2015 Multi storey car park and associated works considered the range of potential impacts on the camp and concluded:

- the proposal was unlikely to have a significant impact on the GHFF colony
- the report identified measures to manage risks to the colony during the construction and post-construction phases; and
- confirmed that no Species Impact Statement or EPBC Act referral was required (Section 4.1 of DA Report No 310/2015 by Executive Planner).

The above 2 developments occurred between 2016 and 2019, and during these periods, the camp remained occupied with no apparent reductions in GHFF numbers.

PLR construction commenced in 2019. Results of monitoring for the PLR revealed high noise construction activities caused only low levels of disturbance and did not seem to impact the camp overall with no obvious changes in GHFF numbers (see Table 10 and Table 11).

Dependent young and nursing females were observed during the survey, however these were not visibly impacted by the high-noise construction works (Narla 2020 22 October).

Table 10 Results of monitoring during construction

Date	Sound source	Time started	Time finished	Disturbance (%) to GHFF camp
23/10/2020	Plane overhead	7:45am	7:47am	Small (5-10%)
23/10/2020	Excavator digging	8:15am	8:30am	No disturbance
23/10/2020	Hammering metal	9:30am	9:45am	No disturbance
23/10/2020	Cutting saw	10:05am	10:14am	No disturbance
23/10/2020	Cutting saw	10:30am	10:40am	No disturbance
23/10/2020	Cutting saw	12:32pm	12:40pm	No disturbance
23/10/2020	Cutting saw	1:25pm	1:31pm	No disturbance
11/11/2020	Plane overhead	7:39am	7:40am	No disturbance
11/11/2020	Jackhammering	7:40am	7:41am	No disturbance
11/11/2020	Jackhammering	7:45am	7:50am	No disturbance
11/11/2020	Plane overhead	7:48am	7:48am	No disturbance
11/11/2020	Material being loaded (metallic banging)	7:58am	7:59am	No disturbance
11/11/2020	Jackhammering	8:05am	8:06am	No disturbance
11/11/2020	Jackhammering	8:11am	8:15am	No disturbance
11/11/2020	Jackhammering	8:25am	8:28am	No disturbance
11/11/2020	Helicopter overhead	8:34am	8:35am	No disturbance
11/11/2020	Jackhammering	8:39am	8:40am	No disturbance
11/11/2020	Helicopter	8:43am	8:44am	No disturbance
11/11/2020	Plane overhead	8:54am	8:54am	No disturbance
11/11/2020	Jackhammering	8:54am	8:55am	No disturbance
11/11/2020	Jackhammering	9:19am	9:25am	No disturbance
11/11/2020	Light plane overhead	9:29am	9:36am	No disturbance
11/11/2020	Ride-on lawn mower (council)	9:42am	9:49am	Small (5-10%)
11/11/2020	Plane overhead	9:49am	9:49am	No disturbance
11/11/2020	Ride-on lawn mower (council)	9:49am	9:54am	Small (5-10%)
11/11/2020	Ride-on lawn mower (council)	9:59am	10:00am	Small (5-10%)
11/11/2020	Chainsaw	10:13am	10:14am	No disturbance
11/11/2020	Ride-on lawn mower (council)	10:24am	10:29am	Small (5-10%)
11/11/2020	Light plane overhead	10:39am	10:39am	No disturbance
11/11/2020	Ride-on lawn mower (council)	10:52am	10:52am	Small (5-10%)

Date	Sound source	Time started	Time finished	Disturbance (%) to GHFF camp
11/11/2020	Chainsaw	10:56am	10:57am	No disturbance
11/11/2020	Helicopter overhead	11:30am	11:30am	No disturbance
12/11/2020	Jackhammering	12:52pm	12:54pm	No disturbance
12/11/2020	Jackhammering	12:59pm	1:01pm	No disturbance
12/11/2020	Chainsaw	1:01pm	1:05pm	No disturbance
12/11/2020	Jackhammering	1:04pm	1:06pm	No disturbance
12/11/2020	Jackhammering	1:10pm	1:13pm	No disturbance
12/11/2020	Jackhammering	1:21pm	1:25pm	No disturbance
12/11/2020	Small plane overhead	1:23pm	1:24pm	No disturbance
12/11/2020	Mulcher	1:31pm	1:36pm	No disturbance
12/11/2020	Jackhammering	1:37pm	1:39pm	No disturbance
12/11/2020	Jackhammering	1:46pm	1:49pm	No disturbance
12/11/2020	Mulcher	1:55pm	2:01pm	No disturbance
12/11/2020	Mulcher	2:05pm	2:09pm	No disturbance
12/11/2020	Jackhammering	2:11pm	2:13pm	No disturbance
12/11/2020	Plane overhead	2:12pm	2:12pm	No disturbance
12/11/2020	Jackhammering	2:17pm	2:19pm	No disturbance
12/11/2020	Jackhammering	2:21pm	2:23pm	No disturbance
12/11/2020	Jackhammering	2:37pm	2:39pm	No disturbance
12/11/2020	Jackhammering	2:42pm	2:46pm	No disturbance
12/11/2020	Jackhammering	2:51pm	2:53pm	No disturbance
12/11/2020	Jackhammering	2:57pm	2:39pm	No disturbance
12/11/2020	Helicopter overhead	7:50am	7:52am	No disturbance
12/11/2020	Plane overhead	7:58am	7:59am	No disturbance
12/11/2020	Small plane overhead	8:28am	8:29am	No disturbance
12/11/2020	Plane overhead	8:50am	8:51am	No disturbance
12/11/2020	Plane overhead	8:53am	8:55am	No disturbance
12/11/2020	Excavator moving	9:12am	9:14am	No disturbance
12/11/2020	Plane overhead	9:23am	9:24am	No disturbance
12/11/2020	Jackhammering	9:30am	9:33am	No disturbance
12/11/2020	Jackhammering	9:36am	9:40am	No disturbance
12/11/2020	Jackhammering	9:42am	9:44am	No disturbance
12/11/2020	Chainsaw	9:44am	9:45am	No disturbance
12/11/2020	Jackhammering	9:45am	9:46am	No disturbance
12/11/2020	Plane overhead	9:51am	9:52am	No disturbance
12/11/2020	Jackhammering	10:00am	10:05am	Small (5-10%)
12/11/2020	Jackhammering	10:12am	10:14am	No disturbance
12/11/2020	Chainsaw	10:14am	10:15am	No disturbance
12/11/2020	Jackhammering	10:16am	10:18am	No disturbance

Date	Sound source	Time started	Time finished	Disturbance (%) to GHFF camp
12/11/2020	Plane overhead	10:18am	10:19am	No disturbance
12/11/2020	Jackhammering	10:19am	10:22am	Small (5-10%)
12/11/2020	Jackhammering	10:26am	10:28am	Small (5-10%)
12/11/2020	Jackhammering	10:32am	10:35am	Small (5-10%)
12/11/2020	Chainsaw	10:32am	10:34am	No disturbance
12/11/2020	Jackhammering	10:38am	10:40am	Small (5-10%)
12/11/2020	Chainsaw	10:43am	10:44am	Small (5-10%)
12/11/2020	Chainsaw and Jackhammering	10:49am	10:49am	Moderate (15-20%)
12/11/2020	Mulcher	10:54am	10:56am	Small (5-10%)
12/11/2020	Mulcher	12:02pm	12:05pm	No disturbance
12/11/2020	Chainsaw	12:08pm	12:12pm	No disturbance
12/11/2020	Jackhammering	12:12pm	12:15pm	No disturbance
12/11/2020	Mulcher	12:14pm	12:16pm	Small (5-10%)
12/11/2020	Jackhammering	12:21pm	12:25pm	No disturbance
12/11/2020	Jackhammering	12:26pm	12:28pm	No disturbance
12/11/2020	Jackhammering	12:47pm	12:50pm	No disturbance
12/11/2020	Plane overhead	12:50pm	12:51pm	No disturbance
19/11/2020	Ride-on lawn mower (council)	7:43am	8:04am	Small (5-10%)
19/11/2020	2 whipper snippers and ride-on lawn mower (council)	8:04am	8:10am	Small (5-10%)
19/11/2020	2 whipper snippers and ride-on lawn mower (council)	8:10am	8:13am	Small (5-10%)
19/11/2020	3 whipper snippers (council)	8:18am	8:18am	Small (5-10%)
19/11/2020	3 whipper snippers (council)	8:23am	8:27am	Small (5-10%)
19/11/2020	Plane overhead	9:07am	9:07am	No disturbance
19/11/2020	Jackhammering	9:09am	9:10am	No disturbance
19/11/2020	Wood chipper	9:38am	9:38am	No disturbance
19/11/2020	Chainsaw	10:00am	10:01am	No disturbance
19/11/2020	Hammering	12:01pm	12:03pm	No disturbance
19/11/2020	Policy siren	1:00pm	1:01pm	No disturbance
19/11/2020	Plane overhead	1:12pm	1:36pm	No disturbance
19/11/2020	School kids	2:40pm	2:41pm	Small (5-10%)
21/11/2020	Unknown	8:16am	8:16am	Small (5-10%)
21/11/2020	Plane/jackhammering	8:32am	8:33am	No disturbance
21/11/2020	Chainsaw	8:33am	8:34am	No disturbance
21/11/2020	Saw/cutting	8:42am	8:42am	No disturbance
21/11/2020	Chainsaw	8:47am	8:47am	No disturbance

Source: Narla Environmental 2020

Table 11 Parramatta Park camp monitoring data

Year	Month	GHFF count
2007	May	8,254
	Jul	1,0074
	Aug	1,0391
2010	Mar	5,700
	Jun	5,700
	Jul	3,000
	Aug	3,500
	Sep	2,500
	Oct	2,500
	Nov	2,600
	Dec	2,900
2011	Jan	5,700
	Feb	5,400
	Mar	3,000
	Apr	4,900
	May	3,900
	Jun	4,800
	Jul	5,800
	Aug	5,300
	Sep	7,600
	Oct	7,000
	Nov	3,800
	Dec	4,800
2012	Jan	5,200
	Feb	5,200
	Mar	4,200
	Apr	300
	May	900
	Jun	3,900
	Jul	5,200
	Aug	9,300
	Sep	6,500
	Oct	7,900

Year	Month	GHFF count
	Nov	5,900
	Dec	3,800
2013	Jan	5,200
	Feb	3,800
	Mar	3,300
	Apr	4,900
	May	4,600
	Jun	2,400
	Jul	5,500
	Aug	13,200
	Sep	14,400
	Oct	11,000
	Nov	7,700
	Dec	7,900
2014	Jan	10,400
	Feb	11,100
	Mar	9,400
	Apr	15,500
	May	16,700
	Jun	15,700
	Jul	9,400
	Aug	9,700
	Sep	14,000
	Oct	14,800
	Nov	13,600
	Dec	9,400
2015	Jan	15,700
	Feb	12,400
	Mar	16,100
	Apr	12,200
	May	15,700
	Jun	34,400
	Jul	29,700
	Aug	17,300

Year	Month	GHFF count
	Oct	13,400
	Nov	15,900
	Dec	17,200
2016	Jan	16,300
	Feb	17,600
	Mar	14,600
	Apr	8,700
	May	12,400
	Jun	18,700
	Aug	10,300
	Nov	14,400
2017	Feb	9,600
	May	13,200
	Aug	13,600
	Nov	9,900
2018	Feb	10,600
	May	14,300
	Aug	11,126
	Dec	11,245
2019	Feb	13,105
	Apr	13,200
	May	5,230
	Jun	8,720
	Jul	9,560
	Aug	9,000
	Sept	9,895
	Oct	13,500

Sources: J Martin 2018 (pers. comm.; Ecosure 2019

In summary:

- Since 2016, there have been several consecutive construction projects within 80 to 300 m of the Parramatta GHFF camp. These have not caused obvious impacts to the camp, with camp numbers remaining stable.
- During construction monitoring for the PLR project, chain sawing and jackhammering were the only construction activities that caused minor disturbance. Park maintenance activities

(e.g. mowing, mulching), albeit closer to the camp than the PLR Project construction activities, caused more frequent disturbance.

- Based on the highly urban environment of the Parramatta GHFF camp, it is likely that the flying-foxes have habituated to disturbance. Considerable measures were also implemented as part of the PLR project to avoid construction impacts.

Case Study 2 – Commonwealth Park camp, ACT

Monitoring program, National Capital Authority

The 2019 – 2020 monitoring program aimed to gather data on flying-fox behaviour during:

- periods of rest (i.e. without disturbance)
- periods of potential stress
- during park operations and events.

It was envisaged this data could:

- be compared with noise emission data collected by qualified noise consultants (see WSP noise modelling below)
- assist in determining which operations or events represent a risk to flying-fox welfare
- assist in determining appropriate levels of mitigation or management.

Eight monitoring events were undertaken due to seasonally low numbers (only 44 flying-foxes were recorded on 28 September) as well as COVID-19 restrictions causing cancellation of some events in 2020. Table 12 provides a summary of the results of noise monitoring (WSP 2020) and flying-fox behaviour during Park monitoring (Ecosure 2020).

Table 12 Noise monitoring at the Commonwealth Park camp during park maintenance and events

Event	Date	Flying-fox count	Sound level dB				Minutes for noise level to drop (either flying-fox or event) after sound event ended	Comments	Flying-fox observations
			Average (Leq)	Average weighted (LAeq)	Exceeded 10% of time (L10)	Maximum (Lmax)			
Background noise monitoring	Nov and Dec 2019	~624 – 2,090	63	52	68	72	n/a	General ambient noise	Ecosure not on site
Post tree-felling and lawn mowing	5/11/19	624	75	63	71	80	n/a	Bats were quiet and calm during the count, then became agitated, lifted off and flew around the camp (30% bats) after lawn mower began between Stage 88 and camp at 1230.	Ecosure not on site.
Live event Carols by Candlelight	14/12/19	2,088	93	76	97	104	10	Crowds, amplified music, and speech ended at 2115. Minutes for noise level to drop **not** likely related to flying-fox.	Mostly undisturbed by music, though some agitation (vocalising) as children played in the understory beneath them.
Live event Australia Day	26/01/20	4,765	79	69	73	n/a	30	Crowds, amplified music, and speech ended 1335. Minutes for noise level to drop is likely related to flying-fox.	Constant chatter and occasional fanning between 8:00 am and 9:35 am. Bats behaviour was normal (chatting) – with no particular response while planes and helicopters were flying overhead. This included the Roulettes display, when they passed multiple times with various stunts. At 9:35 am the 21 gun salute began as well as fighter jets flying low over Commonwealth Park. Over 75% of the bats in the camp lifted off and were flying or agitated for up to 30 mins after the blasts ended. ~10% of camp relocated to trees outside the normal roost extent for the camp (on the north or far west of Stage 88, over Lake Burley Griffin) Injured bats (from recent hailstorm) fell into the understory and were rescued by ACT Wildlife and NCA-engaged veterinarian, including some mothers with pups. Rate of bats falling was consistent between 8am and 3pm but did not appear to increase after gun salute.
Live event Cold Chisel	30/01/20	3,447	91	83	86	n/a	20	Crowds, amplified music, and speech finished at 2150. Minutes for noise level to drop NOT likely related to flying-fox.	Flying-foxes did not appear agitated by Cold Chisel opening or main act, but were constantly fanning and around 25% of individuals were roosting around the trunks or lower down the tree than usual. None observed in the understory. Individuals were difficult to count due to heat stress clumping behaviour.
Live event Symphony in the Park	08/03/20	3,712	84	74	77	n/a	25	Crowds, amplified music, and speech finished at 2200. Minutes for noise level to drop NOT likely related to flying-fox. Flying-fox fly out 1745. Rain will impact noise logging (WSP 2020).	Ecosure not on site.
Park maintenance	05/05/20	1,166	74	64	67	n/a	5	Lawnmower and chipper 0850	Ecosure not on site.
			70	58	62	n/a	20	Chainsaw 1025	Ecosure not on site.

n/a Not available.
Source: WSP 2020; flying-fox data Ecosure 2020

In summary:

- Flying-foxes appeared most impacted by sudden loud noises (e.g. gun salutes), which caused a large proportion of the population (75%) to lift. A smaller number also dispersed to other less commonly used areas of the roost therefore availability of alternative roost sites is a consideration.
- Prolonged noise (e.g. concerts) caused some stress response (e.g. wing fanning) but this varied depending on the concert. Carols by Candlelight provoked little response in comparison to the Cold Chisel concert which may suggest that more 'raucous' noise has a bigger impact.
- Temperature needs to be considered as a contributing or cumulative factor as heat stress responses were also observed during the Cold Chisel event.
- The monitoring program showed that flying-foxes were able to settle within around 30 minutes of a disturbance activity or event. Appropriate intervals between disturbance events need to be considered to ensure flying-foxes have adequate rest periods during events especially during vulnerable periods (e.g. breeding season or extreme weather events).

Case Study 3 – Remembrance Drive camp, Qld

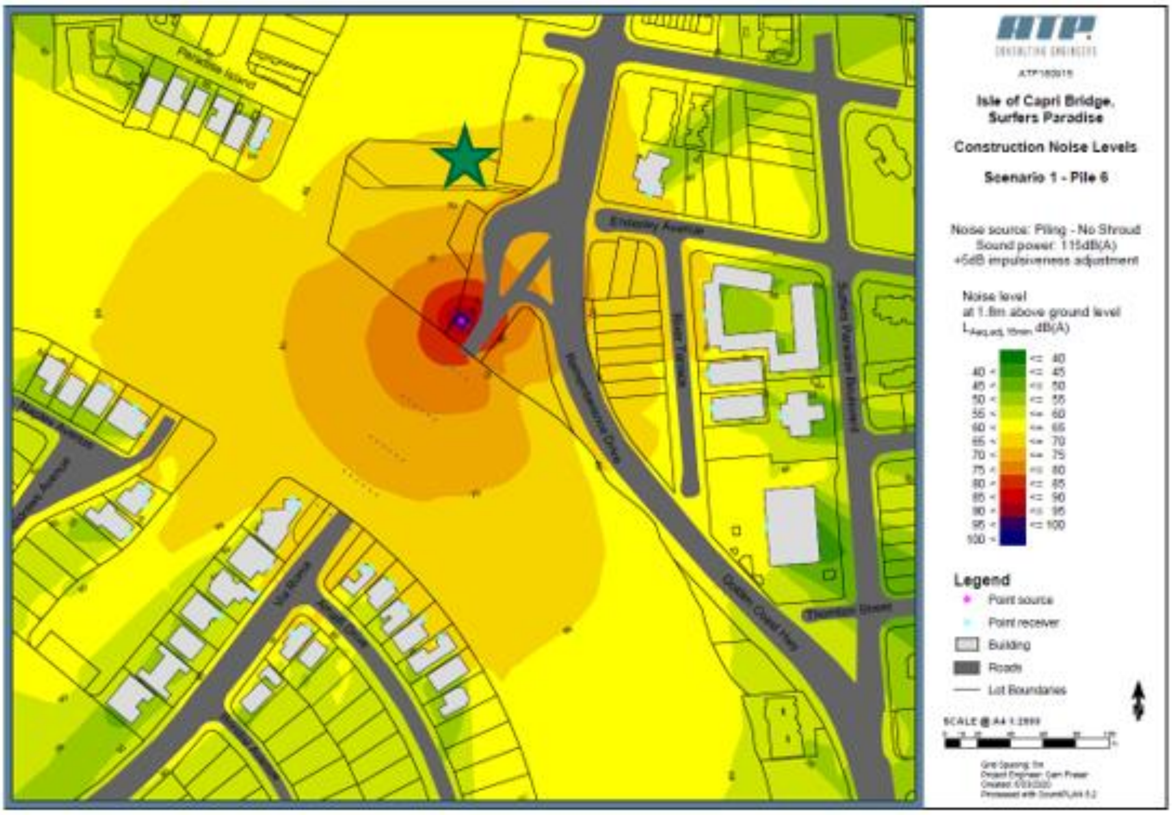
Isle of Capri Decongestion Project, City of Gold Coast

A small number of black flying-foxes (*Pteropus alecto*; BFF) were monitored as part of a bridge duplication construction project at Remembrance Drive, Isle of Capri, Gold Coast. Noise modelling for bridge piling was provided by the construction contractor (Figure 1 below, where camp is denoted by the green star). Activities included piling, drilling and heavy vehicle traffic.

The black flying-fox camp is located adjacent to the Gold Coast Highway and is normally exposed to high levels of traffic including, trams, sirens and motorcycles. The camp is also located on a creek used by recreational watercraft traffic such as jet-skis.

Monitoring by a flying-fox specialist was undertaken between 1 October 2020 to 29 January 2021 during the pregnancy and crèching period of the BFF. While noise monitoring was not undertaken, modelling predicted construction noise at the camp would be approximately 6570 dB. Monitoring showed little to no behavioural response by flying-foxes to construction activities. Flying-fox numbers remained constant during the entire works program and individuals continued to rest even during higher risk activities (e.g. piling). There was one observation by the ecologist of flying-foxes being 50 m further north within roost vegetation upon arrival to site. It was determined from the road spray-down driver that he had sprayed the trees (comprising the roost) to reduce the smell of ibis co-roosting in the camp. The driver was discouraged from spraying water on the roost and no further disturbances were observed.

Figure 1 Example of noise modelling near camp



Note: Camp denoted by green star.

In summary:

- Flying-foxes that are habituated to noise and presence of vehicles may not be disturbed by new noise sources, even impulsive sounds (e.g. piling).
- New or unexpected disturbances (e.g. spraying of water) can provoke avoidance behaviour.
- Regular flying-fox monitoring during construction allows the timely identification and rectification of stimuli causing disturbance and provides sufficient detail to identify specific stimuli that resulted in a disturbance.

Case Study 4 – Lions Head Park camp, Qld

Ongoing slope remediation works, City of Gold Coast

A small number of BFF and GHFF were monitored as part of ongoing slope remediation works at Lions Head Park, Miami between 2015 and 2017, and again in 2020. Roost habitat extends 140 m from the edge of the work area. Flying-foxes remained at the camp during slope remediation works. Ongoing monitoring show that low numbers of flying-foxes remain at this camp all year round (Table 13) and remained present during tree removal works approximately 50 m from the camp in 2017 (Table 14).

Table 13 National Flying-fox monitoring program data for Lions Head

Date	Month	Year	BFF	GHFF	LRFF	SFF	FF total	DES camp ID	District	CSIRO ID
18-Aug-14	8	2014	15	0	0	0	15	300	Burleigh	808

Date	Month	Year	BFF	GHFF	LRFF	SFF	FF total	DES camp ID	District	CSIRO ID
19-Sep-14	9	2014	30	0	0	0	30	300	Burleigh	808
21-Nov-14	11	2014	40	5	0	0	45	300	Burleigh	808
23-Feb-15	2	2015	100	0	0	0	100	300	Burleigh	808
12-Nov-15	11	2015	80	0	0	0	80	300	Burleigh	808
20-Nov-15	11	2015	50	0	0	0	50	300	Burleigh	808
22-Feb-16	2	2016	0	0	0	0	0	300	Burleigh	808
20-May-16	5	2016	22	0	0	0	22	300	Burleigh	808
21-Aug-16	8	2016	0	0	0	0	0	300	Burleigh	808
20-Feb-17	2	2017	12	0	0	0	12	300	Burleigh	808
20-May-17	5	2017	20	0	0	0	20	300	Burleigh	808
26-Aug-17	8	2017	45	0	0	0	45	300	Burleigh	808
17-Nov-17	11	2017	16	24	0	0	40	300	Burleigh	808
16-Nov-18	11	2018	31	0	0	0	31	301	Burleigh	808
15-May-19	5	2019	62	0	0	0	62	302	Burleigh	808
15-Aug-19	8	2019	60	0	0	0	60	303	Burleigh	808
21-Feb-20	2	2020	50	0	0	0	50	304	Burleigh	808
15-May-20	5	2020	47	0	0	0	47	305	Burleigh	808
21-Aug-20	8	2020	51	0	0	0	51	306	Burleigh	808

BFF Black flying-fox. **GHFF** Grey-headed flying-fox. **LRFF** Little red flying-fox. **SFF** Spectacled flying-fox. FF flying-fox. **DES camp ID** Department of Environment and Science identification. **CSIRO ID** CSIRO identification.

Table 14 Monitoring at Lions Head Park camp 21 September to 15 October 2017

Category	Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu
Date	21-Sep-17	22-Sep-17	23-Sep-17	24-Sep-17	25-Sep-17	28-Sep-17	29-Sep-17	30-Sep-17	15-Oct-17
Black Flying-fox (no.)	59	41	41	41	47	64	101	77	87
Pregnant females (no.)	2	1	1	1	1	2	3	0	3
Dependent young (no.)	0	0	0	0	0	0	0	0	6
Notes	Mixture of sub adult/adult males and females	Mixture of sub adult/adult males and females	Mixture of sub adult/adult males and females	Mixture of sub adult/adult males and females	Mixture of sub adult/adult males and females	Mixture of sub adult/adult males and females	Mixture of sub adult/adult males and females	Mixture of sub adult/adult males and females	n/a
Works	n/a	n/a	Veg works started 7:30, 20% colony lifted for 30 seconds and settled 40 m away in the roost. Slept soundly for remainder of day	FF chatty this morning but again slept soundly the entire with little or no disturbance	FF slept soundly again and being the end of the week showed no signs of stress from the weeks veg works	FF very quiet this morning	FF little bit flighty today but because of the increase in numbers, the new arrivals would not have been familiar with machinery sounds. For most of the day they slept soundly	FF slept soundly for the majority of the day until arborist moved the logs under the colony. They lift for 30 seconds then landed. They were restless until the crane left then slept soundly	Post veg works monitoring

n/a Not available.
Source: Ecosure, 2017

In summary:

- The small number of flying-foxes at this site displayed little response to remediation works, even with tree removal occurring 50 m from their location.
- The arrival of new individuals at a site may cause disruption and / or those individuals may be more prone to disturbance if they are not habituated to the ongoing anthropogenic activities that occur near the camp.

Case Study 5 – Palm Beach and Currumbin camps, Qld

Pacific Highway upgrade, Department of Transport and Main Roads and Seymour Whyte

The Palm Beach roost was first recorded in June 2010. Since that time, a small number of BFF have occupied the roost almost continuously between 2010 and 2014 with numbers ranging from <100 up to a maximum of 500 recorded in July 2012. No count data is available between 2014 to 2018, and the last count of 320 occurred in April 2019.

The Currumbin roost was first observed in May 2019, with 56 BFF recorded in January 2020.

The Pacific Highway upgrade began in May 2020. A small number of BFF continued to occupy both the Palm Beach and Currumbin camps adjacent to the Highway during day and nights works, which included tree removal, bridge construction, road widening and road-related construction. A buffer zone of 200 m was drawn around the camps as part of the roost management plan. This plan was developed prior to the project footprint being finalised with the aim to reduce impacts to flying-foxes and the risk of the camp splintering during early works. Upon refining the construction footprint and observations of flying-foxes behaviour at the site, the 200 m buffer was reduced to 100 m (Ecosure pers. Obs. 2015-2020).

Between 84 and 500 BFF were recorded at the Palm Beach roost and up to 35 individuals were observed within the Currumbin roost between the 29 March and 21 April 2021 during the flying fox monitoring period (Table 15).

Clearing works adjacent to (within 100 m) of both roosts were conducted during the daytime in accordance with the roost management plan and supervised by a person knowledgeable about flying foxes. Works were conducted without incident or major stress event.

Table 15 Pacific Highway upgrade BFF monitoring data

Camp	Date	Total BFF
Currumbin	29/03/2021	16
Palm Beach	29/03/2021	500
Currumbin	30/03/2021	1
Currumbin	06/04/2021	6
Currumbin	07/04/2021	13
Currumbin	09/04/2021	15
Currumbin	12/04/2021	21
Currumbin	13/04/2021	32
Currumbin	14/04/2021	35
Currumbin	15/04/2021	24

Camp	Date	Total BFF
Palm Beach	18/04/2021	170
Palm Beach	19/04/2021	110
Palm Beach	20/04/2021	84
Palm Beach	21/04/2021	160

Source: Biodiversity Australia courtesy of TMR

In summary:

- Flying-foxes continued to occupy the sites during construction and appear to be habituated to traffic and other anthropogenic noises, though noise levels were not recorded during construction. Variation in abundance at the roosts seems consistent with previous monitoring.
- Original 200 m buffer was able to be decreased to 100 m as no significant disturbance behaviours were observed.

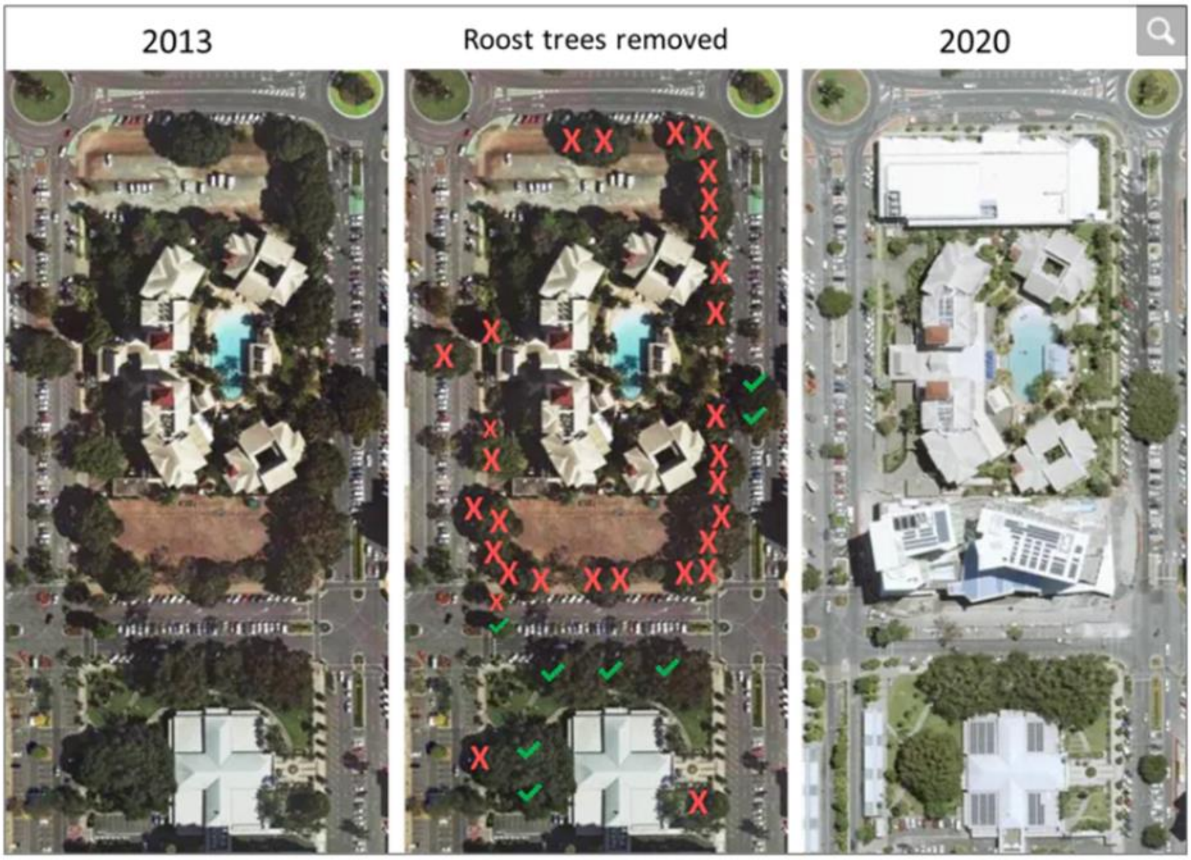
Case Study 6 – Cairns City camp, Qld

Multiple developments

The Cairns City camp was a Nationally Important SFF camp, occupied periodically for over 20 years prior to its intentional dispersal commencing in 2020 (largely justified to avoid impacts discussed below). At times it supported as many as 15,000 SFF representing 15% of the estimated total SFF Australian population of 100,000 individuals (CSIRO 2019).

More than two-thirds of available roosting habitat at the Cairns City camp was removed as part of multiple approved developments in 2014, 2015, 2016 and 2017 (Welbergen et al. 2020b). By 2017, roost habitat was greatly reduced and a large-scale development commenced within 50 m of remaining roost trees (Figure 2, where a cross indicates roost tree removed and a tick shows roost trees retained (Welbergen et al. 2020b). Construction commencing in 2017 was directly opposite remaining roost habitat restricted to trees shown at the bottom of the 2020 image).

Figure 2 Aerial images showing roost habitat loss between 2013 and 2020



Source: Welbergen et al. 2020b.

While true baseline data prior to recent developments from 2014 was not available, Table 16 shows a marked increase in pup mortality and abandonment coinciding with this development.

Table 16 Flying-fox rescue data for the same period 8 September to 10 December

Description	2016	2017
SFF dead at rescue	193	320
SFF live at rescue	173	418
Total SFF dead/rescued	366	738

SFF Spectacled Flying-fox.
Note: Data collated from various sources by the Australasian Bat Society Flying-fox Expert Group.
Source: ABS 2018a

Total mortality and abandonments increased to 1,100 dead or abandoned pups in the 2017 to 2018 breeding season (ABS 2018b).

These numbers are unprecedented for any colony (except for extreme weather events) (ABS 2018a). As reported by carers:

- it was the only camp in the region to see increased mortality
- there were no regional food shortages and it was not a bad tick season (a cause of considerable mortality in SFF)

- there was no evidence that there was any increase in local disturbances at the camp site from previous years.

The only apparent difference was development construction adjacent the camp.

While no definitive causal link could be shown between construction and increasing rates of mortality/abandonment, the consensus amongst flying-fox researchers, local carers, and people monitoring the camp is that this mortality was related to construction (compounded by cumulative impacts of removing trees across multiple projects), specifically associated with:

- overcrowding in remaining trees
- inadequate buffers from construction
- direct mortality associated with collisions
- cranes above the camp
- pile-driving in close proximity (as part of a non-referred development which therefore had limited measures to avoid impacts)
- general stress related to construction activities potentially causing lactation failure.

In summary:

- Where proponents may contribute to cumulative impacts these must be carefully considered when assessing the potential for significant impacts.
- Baseline monitoring is essential to robustly evaluate actions and potential impacts.
- Impacts could have been greatly reduced or avoided with adequate controls (particularly avoiding highly disruptive construction activities, such as overhead cranes and pile-driving, during the rearing season).

Glossary

Term	Definition
action	A project, development, undertaking, activity, a series of activities, or an alteration. Includes, but is not limited to: construction, expansion, alteration or demolition of buildings, structures, infrastructure or facilities; storage or transport of hazardous materials; waste disposal; earthworks; impoundment, extraction and diversion of water; extraction of natural resources; research activities; vegetation clearance; military exercises and use of military equipment; and sale or lease of land (DAWE 2021)
background noise level	Total silence does not exist in the natural and or built environment, only varying degrees of sound. The 'background noise level' is the minimum repeatable level of noise measured in the absence of the noise under investigation and any other short-term noises such as those caused by traffic, lawnmowers, wind in foliage, insects, animals etc. (AAAC 2021)
BFF	Black flying-fox (*Pteropus alecto*)
camp	Camps are the congregation of flying-fox individuals in vegetation in a specific area during the day for resting and social interaction. Individuals within a camp come and go (move between camps) and seasonal variation is common. Some camps are considered permanent as there is a constant presence of flying-foxes (though numbers vary); other camps may be vacant at times. Camps are also commonly called 'roosts' though for the purposes of this document roost refers to the action of resting (see Roosting)
conspecific	Individuals belonging to the same species
crèche	A group of young animals gathered in one place for care and protection usually by one or more adults. Juvenile flying-foxes are crèched overnight at the camp when they become too heavy for adults to carry out foraging (from approximately 4 to 5 weeks of age) and remain flightless until 8 to 12 weeks of age
DAWE	Department of Agriculture, Water and the Environment (Commonwealth)
dB	The decibel (dB) is a logarithmic unit used to measure sound level
dBA	Decibel A-weighted sound levels – describes the relative loudness of sounds in air perceived by humans
DEE	Department of the Environment and Energy (Commonwealth; now DAWE)
DEC	Department of Environment and Conservation (Western Australia)
DES	Department of Environment and Science (Queensland)
DoE	Department of the Environment (Commonwealth; now DAWE)
DPIE	Department of Planning, Industry and Environment (New South Wales)
dust	The generic term used to describe solid airborne particles generated and dispersed into the air by processes such as handling, crushing and grinding of organic or inorganic materials such as rock, ore, metal, coal, wood or grain and stockpiling of materials and wind-blown dust (DEC 2011)
EPBC Act	*Commonwealth Environment Protection and Biodiversity Conservation Act 1999*
FF	Flying-fox
foraging habitat	Forests and other vegetation where flying-foxes feed on blossom and fruit; generally within 10 to 40 km of a camp (Eby 1991 and Westcott et al. 2015 in DAWE 2021a)
fume	An aerosol of solid particles formed by condensation of vapours formed at elevated temperatures. The primary particles are generally very small (less than 0.1 micrometre) and have spherical or characteristic crystalline shapes. Since they may be formed in high number concentrations, they often rapidly coagulate, forming aggregate clusters of low overall density (DEC 2011)

Term	Definition
GHFF	Grey-headed flying-fox (*Pteropus poliocephalus*)
Hz	Hertz – unit of measurement for the pitch of a sound and relates to the number of cycles it completes per second
important camp	For the purposes of this document, an 'important camp' is one that meets criteria to be considered roosting habitat critical to the survival of the GHFF (i.e. a nationally-important GHFF camp), or a camp that may not meet nationally-important camp criteria, but could otherwise be considered important (e.g. a regularly occupied camp within 20 km of foraging habitat critical to the survival of the species); see DAWE 2021a
kHz	Kilohertz = 1,000 Hz
LED	Light-emitting diode
LRFF	Little red flying-fox (*Pteropus scapulatus*)
mist	Droplet aerosol formed by mechanical shearing of a bulk liquid; for example, by atomisation, nebulisation, bubbling, or spraying. The droplet size can cover a very large range, usually from about 2 micrometres to greater than 50 micrometres (DEC 2011)
MNES	Matters of National Environmental Significance
noise	A sound that is loud or unpleasant, or that causes disturbance. See also Sound
OEH	Office of Environment and Heritage (New South Wales; now DPIE)
PLR	Parramatta Light Rail
Pteropid	Fruit bat species
referral	'Referral' of an action involves filling out a referral form and sending it to the Department of the Environment. A referral identifies the person proposing to take the action and includes a brief description of the proposal, the project location, the nature and extent of any potential impacts, and any proposed mitigation measures
referral guideline	Referral Guideline for Management Actions in Grey-headed and Spectacled flying-fox Camps (DoE 2015)
Roost(ing)	To roost / roosting refers to the actions of flying-foxes during the day including resting, sleeping or displaying other social behaviours
SFF	Spectacled flying-fox (*Pteropus conspicillatus*)
significant impact	Significant Impact Guidelines 1.1 – Matters of National Environmental Significance (DoE 2013)
skyglow	Brightness of the night sky in a built-up area as a result of light pollution
smoke	Formed by condensation of combustion products, generally of organic materials. The particles are generally liquid droplets with diameters of less than 0.5 micrometre (DEC 2011)
sound	Vibrations that travel through the air or other medium that can be heard when they reach person's or animal's ears. See also Noise
TfNSW	Transport for New South Wales
TMR	Department of Transport and Main Roads (Queensland)

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Version control

Revision no.	Revision date	Details	Prepared by	Reviewed by	Approved by
00	24/05/2021	Noise, light and dust impacts on grey-headed flying-fox camps – assessment guidelines – DRAFT R0	Jess Bracks, Principal Wildlife Biologist (Ecosure) Emily Hatfield, Senior Wildlife Biologist (Ecosure)	Phil Shaw, Managing Director (Ecosure) Dr Rodney van der Ree (University of Melbourne) Department of Agriculture, Water and the Environment	Phil Shaw, Managing Director (Ecosure)
01	15/06/2021	Noise, light and dust impacts on grey-headed flying-fox camps – assessment guidelines – DRAFT R1	n/a	Jess Bracks, Principal Wildlife Biologist (Ecosure) Kaye Currey, Senior Wildlife Biologist (Ecosure)	Phil Shaw, Managing Director (Ecosure)
02	30/06/2021	Noise, light and dust on grey-headed flying-fox camps – Information document	n/a	Dr Rodney van der Ree (University of Melbourne) Department of Agriculture, Water and the Environment Jess Bracks, Principal Wildlife Biologist (Ecosure)	Phil Shaw, Managing Director (Ecosure)
03	15/10/2021	Species-specific guidance: Noise, light and dust impacts on grey-headed flying-fox camps – Information document	n/a	Department of Agriculture, Water and the Environment Jess Bracks, Principal Wildlife Biologist (Ecosure)Kaye Currey, Senior Wildlife Biologist (Ecosure)	Jess Bracks, Principal Wildlife Biologist (Ecosure)

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