Home is where the grass is: Kangaroos in peri-urban communities on the Coffs Harbour Northern Beaches

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"We love our kangaroos, particularly the two females that regularly come into our backyard with their joeys. But looking at the big picture, I think there are too many roos in the Heritage Park area, attracted by an easy feed and a safe life." – Heritage Park Resident

"The numbers of kangaroos are definitely increasing and something needs to be done to control numbers." – Avocado Heights Resident

"Actually a shame to see people completely fence their property in, which reduces kangaroo habitat and pathways. Love seeing kangaroos around and find their presence very positive." – Emerald Beach Resident

"Kangaroos have attacked people in our area. We have spent over $6000 in vet bills for our dogs because of kangaroos." – Heritage Park Resident

"I am too afraid to walk around dawn and dusk as the kangaroos are quite aggressive." – Woolgoolga Resident

"I would like to see residents better informed and better acceptance of them in the environment" – Safety Beach Resident

"I do not consider wild kangaroos to be a concern on the roads for alert drivers who don't speed, nor do I consider them dangerous unless provoked. The biggest threats to kangaroos' lives come from the actions of humans, e.g. (speeding) vehicles and unleashed dogs; therefore I believe the onus is on us to take responsibility in preventing negative/dangerous interactions." – Coffs Harbour Northern Beaches Resident

(A sample of quotes from respondents of the 2015/2016 Kangaroo Community Survey)

Summary

Eastern grey kangaroos, *Macropus giganteus,* are common residents within the coastal-urban communities of the Coffs Harbour Northern Beaches, New South Wales (NSW). They occur in areas of suitable vegetation, such as residential properties, vacant blocks, grassland reserves and golf courses. Their proximity to people often results in a range of interactions. While most interactions are positive, negative interactions often occur. The expanding urban communities and growing numbers of kangaroos on the Coffs Harbour Northern Beaches have resulted in an increase in kangaroo-related incidents. The NSW National Parks and Wildlife Service (NPWS); Wildlife Information, Rescue and Education Service (WIRES), and Coffs Harbour City Council (CHCC) have drafted a Kangaroo Management Plan in light of this issue, to ensure that people and kangaroos can co-exist without conflict. My thesis involved ecological and human dimensions research on kangaroos and human-kangaroo interactions for the purpose of providing information to the NPWS to assist the management plan. My thesis aimed to estimate kangaroo abundance and density, gauge community perceptions and values towards kangaroos, and understand the movement patterns of kangaroos in the peri-urban environment.

I sampled kangaroo populations using direct observation counts at four hotspot sites (Heritage Park, Avocado Heights, the Emerald Beach Headlands and the Safety Beach golf course), and distance sampling at Heritage Park. Estimates revealed that kangaroo abundance was highest at Heritage Park, with the minimum number known to be alive (MNKA) exceeding 300 individuals in October. Overall, density was also high at Heritage Park (up to 2 kangaroos per ha), the Emerald Beach headlands (2.3 to 4.9 kangaroos per ha) and the Safety Beach golf course (1.6 to 2.3 kangaroos per ha). Monthly densities were relatively constant throughout the year, with slight decreases in the winter months.

To gauge community perceptions of kangaroos in the peri-urban matrix, I created an online questionnaire using the program Survey Monkey, and targeted specific communities on the Coffs Harbour Northern Beaches using mail-outs. Community perceptions towards kangaroos were positive overall. However, there were some concerns among residents on potential conflict and vehicle collisions with kangaroos. Respondents also felt strongly that they were uninformed by the NPWS and CHCC regarding human-kangaroo interactions. There was also a clear lack of kangaroo related educational exposure among respondents, who also expressed a strong desire to be provided with relevant information on how to appropriately live with kangaroos in their local area.

I used GPS collars and GPS telemtry backpacks to monitor the movement patterns of 14 male kangaroos at Heritage Park. Kangaroos mainly occurred within the peri-urban landscape, however, only occupied small sections of Heritage Park. The mean range area and core area for four collared kangaroos was 34 hectares and 6.5 hectares respectively, which is approximately half of the home ranges for eastern grey kangaroos recorded in woodland reserves and farmland areas. Kangaroos used on average 4.6 properties a day and an average of 15 properties per tracking period, with one individual using a total of 34 properties. The four collared kangaroos showed temporal shifts in their proximity to housing, being closer to houses overnight and further away during the day, although in general movement rates did not change much throughout the day.

These three components of research are all important in increasing the understanding of peri-urban kangaroo populations on the Coffs Harbour Northern Beaches, to assist in developing appropriate management strategies for managing kangaroos and their interactions with people.

Declaration

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

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Contents

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Chapter 1: The eastern grey kangaroo *Macropus giganteus* on the Coffs Harbour Northern Beaches

1.1 Introduction

The Coffs Harbour Northern Beaches is located in the Coffs Coast region of north-east New South Wales (Figure 1.1). The region consists of a diversity of tropical, subtropical and temperate ecosystems (CHCC, 2012). Much of the area comprises of marine parks, nature reserves and state forests, which boast a variety of floral and faunal species. Three large species of macropods are endemic to the Coffs Coast Northern Beaches region. They include the eastern grey kangaroo (*Macropus giganteus*), red-necked wallaby (*Macropus rufogriseus*) and swamp wallaby (*Wallabia bicolor*) (Scotts, 2008). The eastern grey kangaroo is by far the most numerous of the three species, and is the focal species of my thesis.

In recent years, the occurrence of kangaroos in the expanding communities of the Coffs Harbour Northern Beaches have become increasingly problematic. Databases from the local National Parks and Wildlife Service (NPWS) and Wildlife Information, Rescue and Education Service WIRES provide context behind the extent of kangaroo related incidents in the region between 2007 and 2016. The NPWS recorded 40 attacks or threats by kangaroos and WIRES reported 636 call-outs for kangaroo related incidents, which included sick, injured or deceased kangaroos (WIRES, NPWS and CHCC, 2016). These databases are most likely an under-reporting of incidents, however, they highlight the severity of the issue and importance of management actions.

In 2015, the Coffs Harbour City Council (CHCC) and local NPWS began drafting a Kangaroo Management Plan to guide the management of kangaroo populations and their interactions with people in the Coffs Harbour Northern Beaches region. A Kangaroo Management Committee has overseen the formation of the plan throughout 2016. This committee consists of representatives from the NPWS, CHCC, WIRES, the local community, veterinarians, and researchers which included Associate Professor Karl Vernes. While Dr Rajanathan Rajaratnam and I were invited to participate and provide relevant input during committee meetings. The primary objective of the Kangaroo Management Plan was to ensure the positive co-existence of people with a sustainable population of wild kangaroos, which share the peri-urban landscapes of the Coffs Harbour Northern Beaches.

1.2 Thesis aims and objectives

The objective of this thesis was to provide the NPWS and CHCC with relevant information on the ecology of local kangaroos and the perceptions of residents towards them. This thesis consists of several aims, which relate to the understanding and management of peri-urban kangaroos, in the context of the Coffs Harbour Northern Beaches.

These aims include:

- To review the literature in regards to human-kangaroo interactions and management in several documented areas of eastern Australia.

- To report on the abundance and density of kangaroos at several localities which are 'hotspots' for kangaroo activity and associated human-kangaroo conflict.

- Understand community perceptions and values towards resident kangaroos, with a view to assist in the management of human-kangaroo interactions.

- Understand the movement patterns of kangaroos at the high priority locality of Heritage Park, so as to provide a benchmark for potential kangaroo management strategies in peri-urban areas.

1.3 Study areas

Research was focused on several locations along the Coffs harbor Northern Beaches, referred to as kangaroo management 'hotspots' (Figure 1.1). These hotspots include areas with frequent reports of kangaroo related incidents, as well as high densities of kangaroos (WIRES, NPWS and CHCC, 2016). These communities can be classed as peri-urban areas which interlace with the remaining natural habitats. Several sites were adjacent to state forests or NPWS reserves. Heritage Park was the core area of interest throughout this study, providing an ideal example of a peri-urban location in need of kangaroo management.

Figure 1.1. Map showing the study sites on the Coffs Harbour Northern Beaches, NSW, Australia.

1.3.1 Heritage Park

Heritage Park is a rural estate which is officially part of Moonee Beach and located on the western side of the old Pacific Highway (known as Solitary Islands Way) (Figure 1.1). It is approximately 191 hectares (ha) in size and consist of 178 properties (as of December 2015). Heritage Park is characterized by large properties, many of which have retained trees that were present pre-development. There are a mix of unfenced, partially fenced and fully fenced properties throughout Heritage Park, with newer properties typically being fully fenced. There is also ongoing residential development in the southern section of Heritage Park, expanding onto vacant blocks which is often occupied by large numbers of kangaroos. The Pacific Highway and associated fauna fencing restricts movement across the highway, with the exception of a creek to the south which runs under the highway. The Orara East State Forest borders Heritage Park to the west and south, while the northern section merges onto Avocado Heights, although these sites are not connected by any public roads. The Pacific Highway restricts kangaroo dispersal between Heritage Park and vacant land on the eastern side of the highway. Property fencing within Heritage Park also restricts kangaroo distribution, forcing populations to concentrate in large numbers on vacant areas and partially fenced or unfenced properties (Figure 1.2). Therefore, kangaroos appear to exist in a high density, resulting in a perception of overabundance. The high occurrence of human–kangaroo interactions, especially negative interactions, is evident by the frequent reports of kangaroo related incidents. Since 2007, there have been 17 reports of kangaroo attacks on humans at Heritage Park.

Figure 1.2. An example of kangaroos occupying a peri-urban residential property at Heritage Park.

1.3.2 Avocado Heights

Also part of Moonee Beach, Avocado Heights is approximately 178 ha in size and supports 160 properties (Figure 1.1). It connects to Heritage Park to the south and shares similar characteristics to Heritage Park in regards to property size and structure. However, Avocado Heights surrounds several small lakes and also extends into the elevated forested areas to the west. The kangaroo population here has a patchy distribution, although they are more commonly found on properties located near the lakes. There have been five reports of kangaroo attacks at Avocado Heights since 2007.

1.3.3 Emerald Beach

This small coastal locality (covering approximately 48 ha) has a high urban density supporting 603 properties, many of which are holiday homes (Figure 1.1). It includes two grassy headlands; Look-at-me-now (LAMN) and Dammerels, on which kangaroos are predominately found. These headlands were added to the Moonee Beach Nature Reserve in 1995, prohibiting domestic dogs (Scotts, 2008). Since then, residents have noted an increase in kangaroo numbers. Walking tracks connecting the two headlands are frequently used by locals and tourists. The abundance of kangaroos here and their tolerance to human presence makes the headlands a significant tourist attraction, as well as a management hotspot. There are concerns for the ecological impact of kangaroo numbers on the threatened Kangaroo Grass (*Thermeda australis*), which is the focus of another research project conducted by the University of New England (UNE). There is a small population of red-necked wallabies located on the LAMN headland which co-exists with the eastern grey kangaroo population. Since 2007, three attacks by eastern grey kangaroos on humans have been reported at Emerald Beach.

1.3.4 Safety Beach

The small satellite community of Safety Beach (covering approximately 50 ha) is located between the old Pacific Highway and the Pacific Ocean, and is associated with the larger urban center of Woolgoolga (Figure 1.1). Its major feature is an 18-hole golf course, located along the entire northern border of the Safety Beach residential area. There is unrestrictive access from the residential area of Safety Beach, which allows kangaroos to move to and from the golf course with ease. Anecdotal observations by locals indicate a fall in the kangaroo population since the construction of the new Pacific Motorway in 2014. This has caused a reduction in traffic on the old Pacific Highway, resulting in higher kangaroo dispersal onto the

vacant areas of western Woolgoolga. Despite this, the Safety Beach golf course appears to form the 'nucleus' of the kangaroo population within Safety Beach and the surrounding areas (Figure 1.3). There has been one report of a kangaroo attack at Safety Beach since 2007. However, the high potential for negative interactions between kangaroos and people (especially golfers and tourists) made this site a priority for research.

Figure 1.3. Eastern grey kangaroos enjoying the well-managed grass on the 18-hole golf course at Safety Beach.

1.3.5 Woolgoolga

Woolgoolga is a large urban town with approximately 5,000 residents (Figure 1.1). There is a small kangaroo population (single social group of about 20 individuals) which occupies the forested and grassy areas surrounding Woolgoolga's sporting fields and the St Francis Xavier Primary School (Dave Scotts, NPWS/CHCC, pers. comm). The risk of negative interactions between kangaroos and humans near these areas is a specific concern in regards to the safety of children. During quieter periods (i.e. overnight), the population often disperses into the surrounding properties. Personal observations revealed a population of about 80 kangaroos which exist in the rural areas of north-west Woolgoolga. There is ongoing development and future development planned for this area. Since 2007, four kangaroo attacks have been reported in the Woolgoolga area.

Chapter 2: A literature review of kangaroo management in peri-urban areas of eastern Australia

2.1 Summary

When attempting to manage urban wildlife, it is important to understand the ecology of the target species as well as the perceptions and attitudes of local communities towards it. Many large mammal species have established populations in the interface between rural and urban areas, known as the 'peri-urban' interface. The co-occurrence of humans and wildlife in this interface often results in a variety of positive and negative human-wildlife interactions. Large mammals are commonly involved in these interactions and therefore become the focus of peri-urban wildlife management and research. For example, white-tailed deer (*Odocoileus virginianus*) are well-studied large mammals which occur on the fringes of many North American towns. Similarly, peri-urban populations of kangaroos are known to occur at localities throughout eastern Australia.

Wildlife managers are concerned with maintaining the positive interactions with urban wildlife, while more importantly managing the negative interactions that arise from human-wildlife conflict. The major issues associated with peri-urban kangaroos include vehicle collision, aggressive behaviour and property damage. The management of these issues are a challenging task for wildlife managers. Populations that are abundant or perceived as overabundant, usually require population control which is highly contentious. Managers are therefore tasked with implementing appropriate control methods which need to be realistic and cost-effective, as well as socio-politically acceptable. Understanding the context of the management scenario is also important and often requires community engagement. For peri-urban kangaroos, engaging the community can assist in identifying problems, choosing appropriate management actions and developing management plans. This review focuses on the management of peri-urban kangaroo populations in eastern Australia, with specific attention on the Coffs Harbour Northern Beaches.

2.2 An overview of urban wildlife ecology and management

2.2.1 Introduction

Urbanization can be defined as the transformation of wild lands to better suit the needs and desires of humans (Adams and Lindsey, 2010b). This typically involves the replacement of continuous native vegetation with exotic vegetation, open spaces, buildings, and transport infrastructure such as roads and rail lines. Wildlife is defined as "wild animals, usually terrestrial vertebrates whose populations are monitored for exploitation or conservation" (Fryxell et al., 2014). The term 'urban wildlife' usually describes wildlife which are forced to adapt and become part of the urban environment, or survive in what's left of their natural habitat within suburbia (Coulson et al., 2014). Certain species are naturally suited or well adapted to urban environments, while other species may decrease or disappear (Lunney and Burgin, 2004a).

The urban ecosystem is one that is influenced by human attitudes, behaviour, politics and resource control (Adams and Lindsey, 2010b). These types of ecosystems include both grey spaces where built habitats such as buildings and roads cover more than 80% of the area, and green spaces which include remnant habitat patches (undeveloped natural areas), successional habitat patches (such as vacant blocks) and managed vegetation (such as golf courses and public parks) (Adams and Lindsey, 2010b). The vertebrate species that are able to exploit both types of urban spaces are usually birds or small mammals (Adams, 2005), which are known as matrix-occupying species (Garden et al., 2006). In some cases, large mammals occupy the urban fringes and can occur within the urban matrix, which often results in significant human-wildlife conflict (Table 2.1). Urban wildlife management commonly focuses on resolving the impacts and conflicts associated with these large mammals as they are of high social interest and concern (Adams and Lindsey, 2010b).

Table 2.1. Examples of large mammal species involved in urban human-wildlife conflict.

Species	**Location**	**Reference**
Red fox (*Vulpes vulpes*)	Europe	(Baker and Harris, 2007)
Coyote (*Canis latrans*)	North America	(Baker and Timm, 1998)
American black bear (*Ursus americanus*)	North America	(Baruch-Mordo et al., 2014)
White-tail deer (*Odocoileus virginianus*)	North America	(Storm et al., 2007)
Eastern grey kangaroo (*Macropus giganteus*)	Australia	(Coulson et al., 2014)

2.2.2 Urban wildlife management research

The existence of wildlife in urban environments dates back to ancient times with records of scavenging birds and mammals exploiting urban areas of ancient Egypt (Dixon, 1989). The recent acceleration of urbanization in the last century has resulted in a growth of interest in urban wildlife research (Mayer, 2010). Magle et al. (2012) conducted a systematic review of trends in urban wildlife research between 1971 and 2010 from 16 leading animal journals. Their study concluded that there has been an increase in urban wildlife publications since 1971, with the majority coming from North America. However, their study showed publications still remain low despite the rapid increase of urban growth and its associated issues with wildlife. Furthermore, in their study, wildlife management was represented in approximately 30% of urban wildlife publications, with mammals comprising of more than half of the focal taxa in these publications. Presently, the white-tailed deer is the most extensively studied urban mammal species, with an entire issue of the journal *Wildlife Society Bulletin* (see volume 25(2), 1997) dedicated to research on its overabundance in urban environments.

In Australia, a focus on urban ecology has increased in the last few decades with almost 90% of Australia's population now living in urban areas (The World Bank, 2016). The peri-urban interface is where the majority of human and urban wildlife encounters exist and ultimately where active urban management is required (Ballard, 2008). Several Australian organizations and programs such as Urban Ecology Australia, The Australian Research Centre for Urban Ecology, and The Suburban Wildlife Research Group, have been established for urban ecology based research and management (Adams, 2005). The Royal Zoological Society of New South Wales has also conducted several forums regarding research on urban ecology and management (see Lunney & Burgin 2004; Lunney *et al.* 2008).

Research on large urban mammals is perhaps the most important in urban wildlife management due to the substantial and obvious impacts they can cause in urban areas. It is also the most contentious as larger mammals are highly valued by the public and management usually cannot go unnoticed (Herbert, 2004). Parallels exist between Australian and global research involving large urban mammal species based on the central problems associated with human-conflict such as vehicle incidents, aggression and competition for resources and space (Ballard, 2006). For example, such problems exist in urban deer populations of North America, and similarly in urban kangaroo populations of Australia (Adams and Lindsey, 2010a; Coulson et al., 2014). Management of these large herbivores can therefore be analogous, allowing

researchers and managers to assess findings from related research and adopt similar management strategies.

2.3 Peri-urban kangaroos

The various species of kangaroos and wallabies that occur throughout most of Australasia are part of the marsupial superfamily Macropodidae (Sharman, 1989). Macropods make up almost 40% of all marsupial species and 20% of the known number of Australian mammal species (Grigg et al., 1989). Since European settlement, populations of many large macropods have dramatically increased (Jackson and Vernes, 2010). This is primarily due to the various favourable conditions introduced by settlers such as the introduction of watering points, conversion of low quality habitats to pastoral habitats and the persecution of indigenous Australians and dingos (*Canis lupus dingo*) (Montague-Drake and Croft, 2004; Jackson and Vernes, 2010). Many small macropod species (within the critical weight range of 35 grams to 5.5 kilograms) have become endangered or extinct due to the impact of European rabbits (*Oryctolagus cuniculus*), predation by the red fox (*Vulpes vulpes*) and the spread of pastoralism and urbanisation (Edwards, 1989). The larger macropod species have however managed to successfully establish populations in some peri-urban areas of Australia (Table 2.2). This review focuses on perhaps the most urbanised species of macropod, the eastern grey kangaroo.

Table 2.2. Examples of macropod species (other than *Macropus giganteus*) known to occur in peri-urban areas of Australia. Weight data (expressed in kilograms) obtained from Jarman (1989).

Species	**Weight (kg) Male**	**Weight (kg) Female**	**Location**	**Reference**
Swamp Wallaby *Wallabia bicolor*	22	15	Sydney, NSW	(Ramp and Ben-Ami, 2006)
Tamar Wallaby *Macropus eugenii*	9	7	Garden Island, WA	(Chambers, 2009)
Agile Wallaby *Macropus agilis*	30	15	Darwin, NT	(Stirrat, 2003)
Red-necked Wallaby, *Macropus rufogriseus*	20	12	Coffs Harbour, NSW	Scotts (2008)
Western Grey Kangaroo *Macropus fuliginosus*	72	39	Perth, WA	(Mayberry et al., 2014)

2.3.1 The eastern grey kangaroo

The eastern grey kangaroo has been well studied in Australia (Caughley et al., 1987; Grigg et al., 1989; Dawson, 1995; Van Dyck and Strahan, 2008) primarily due to their abundance and impact on the Australian environment, society and economy. It is distributed almost continuously from north-eastern Queensland to south-eastern Australia (Dawson, 1995), favouring habitats with high levels of grass cover combined with trees and shrubs which provide shelter (Caughley, 1964). It is a sexually dimorphic species with adult males weighing up to 75kg, while adult females are usually restricted to 40kg (Jarman, 1989).

Eastern grey kangaroos are herbivorous and usually graze in the evening, at night and in the morning (Dawson, 1995). During the day, they commonly rest under the cover of trees or shrubs (Poole, 1998). They are a highly gregarious species, often found in groups with more than 10 individuals (Kaufmann, 1975). Groups usually consist of equal numbers of males and females where the males exist in a dominance hierarchy and exhibit intra-specific aggression when females are in estrous (Dawson, 1995). Female eastern grey kangaroos are polyestrous all year round, with births peaking in summer (Poole, 1983). Adult females are almost continuously pregnant and can exhibit diapause while the current joey is still in the pouch. Females are therefore able to produce young every year and can do so for up to 10 years (Quin, 1989).

Success in the urban environment

Kangaroos are well suited for surviving within and exploiting the habitat resources within the peri-urban matrix (Coulson, 2008). They often live on the fringes of urban areas where managed vegetation (e.g. golf courses, parks and residential lawns) overlap and form ecological corridors with their more natural habitats in National Parks, State Forest or rural grasslands (ACT Kangaroo Management Plan, 2010). This peri-urban matrix provides an ideal habitat mosaic of forage and cover, allowing kangaroos to occur in both grey and green urban spaces (Coulson et al., 2014). Furthermore, large group sizes of urban kangaroos allow for less investment in vigilance and more time spent on other activities such as foraging or mating (Colagross and Cockburn, 1993). A combination of these factors has promoted dramatic increases in kangaroo numbers in some urban and peri-urban residential communities. Such examples can be seen in places along the North Coast of NSW, including the Coffs Harbour Northern Beaches and Grafton.

Ecological impact

The eastern grey kangaroo is an important natural component of grassy ecosystems (Dawson, 1995). Grazing maintains uniform short grass which can both exclude grassland species and reduce the chance of grassfires (Neave and Tanton, 1989). Overgrazing by overabundant kangaroo populations can, however, result in the degradation of habitats that are critical to plant species of grassy ecosystems (Van Dyck and Strahan, 2008). For example, on headlands found in the Moonee Beach Nature Reserve on the Coffs Coast, overgrazing and trampling may have potential effects on floral species such as Kangaroo Grass (*Themeda australis*) (Scotts, 2008). Kangaroos also have the potential to increase the risk of disease to humans through contamination of water supplies through faecal-borne pathogens. In the peri-urban context, the transition of zoonotic diseases such as *Cryptosiridium*, would be of most concern (Koehler et al., 2014). Similarly, in North America, the proximity of urban deer are known to increase the spread of disease to humans, an example being the transmission of Lyme disease through the deer tick *Ixodes scapularis* (Magnarelli et al., 1995).

Threats to peri-urban kangaroos

Despite the ability of kangaroos to successfully exploit the urban environment, they are still faced with numerous threats to their welfare (Table 2.3).

Table 2.3. A summary of potential threats to kangaroo populations in peri-urban areas.

Threat	Description
Habitat loss/fragmentation	Urban expansion results in habitat fragmentation as well as the depletion of natural habitats, which has direct impacts on kangaroo gene flow and population numbers.
Mortality from road kills	Increases in human road traffic and larger motorways have increased the potential of kangaroos to be killed or injured in vehicle collisions.
Disturbance from dogs	Dogs and other pets may pose welfare implications to kangaroos. Pet dogs are known to attack and cause stress to kangaroos along the Coffs Coast (Ballard, 2006).
Overabundant populations	Kangaroos in overabundant populations are vulnerable to density-dependent effects such as the prevalence of diseases and reduction in fecundity and body health (Coulson, 2007). While this may not be an issue for every peri-urban population, it is an important threat to consider and carefully monitor.

2.4 Human – kangaroo interactions

Human perceptions of kangaroos are usually influenced by the interactions that occur between the two. Australians variously perceive kangaroos as a national icon, an important component of the native fauna, a resource and a pest (Pople and Grigg, 1999). These perceptions of kangaroos are not necessarily mutually exclusive and can be a combination of some or all of them, depending on the situation (Pople and Grigg, 1999). For areas where humans and kangaroos occur sympatrically (such as on urban fringes), human perceptions and values towards kangaroos are an essential part to the management of kangaroo populations (Ballard, 2006). The basic human values towards kangaroos, based on a typology of values of large mammals in North America by Kellert and Smith (2000); are summarized in Table 2.4.

Table 2.4. Examples of human values towards kangaroos in peri-urban areas.

Values towards kangaroos	**Examples in peri-urban settings**
Naturalistic – Personal pleasure derived from encountering and experiencing direct contact with kangaroos.	Residents being able to observe kangaroos easily without having to go into the 'wild'.
Humanistic – The emotional affinity people have for kangaroos.	People can form emotional attachment to kangaroos who which they may share a neighbourhood with.
Aesthetic – The attraction and appeal of kangaroos, especially in their archetypal state.	The awesome display of intra-specific aggression between two large males when females are in estrus.
Moralistic – The moral importance of kangaroos.	People may feel a sense of moral or ethical responsibility to conserve and protect kangaroos.
Negativistic – Kangaroos can provoke aversive reactions in people who are fearful or anxious due to varying circumstances.	Experiences of aggressive behaviour or negative interactions from kangaroos can invoke fear in humans.
Scientific – Studying and understanding kangaroos.	Knowledge can enhance the capacity to appropriately manage and safely live with kangaroos.

Human-kangaroo interactions in peri-urban areas have been studied in several locations along eastern Australia (Figure 2.1). These studies are based on the problems associated with high density kangaroo populations in urban communities and the positive and negative outcomes of frequent interactions.

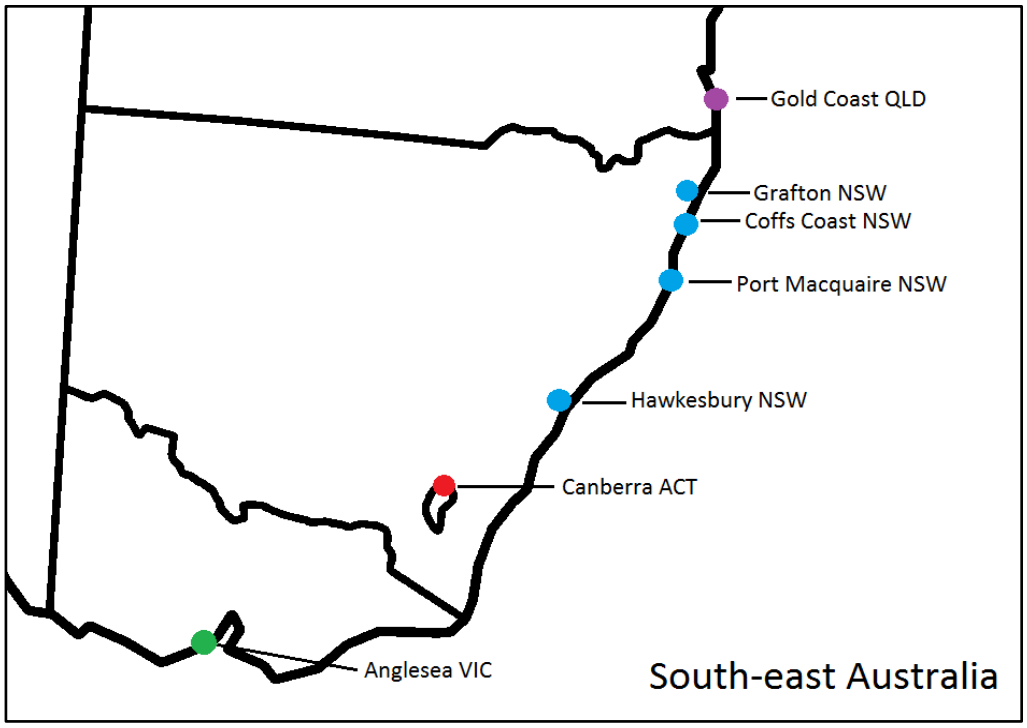

Figure 2.1. Locations where peri-urban kangaroos have been studied in relation to human – kangaroo interactions. These localities are: Gold Coast (Higginbottom and Page, 2010), Grafton (Jarman and Gray, 2000), the Coffs Coast (Ballard, 2006), Port Macquarie (Ballard, 2006, 2008), the Hawkesbury (Chalk, 2007), Canberra (ACT Kangaroo Management Plan, 2010) and Anglesea (Inwood et al., 2008; Coulson et al., 2014)

2.4.1 Positive outcomes

The presence of kangaroos in urban areas can provide aesthetic and economic benefits to residents and visitors (Inwood et al., 2008). Residents living in proximity to kangaroos have usually chosen to do so to be closer to nature (Ballard, 2006). The peri-urban setting allows for residents to frequently enjoy the presence of native wildlife at their doorstep, whilst still remaining in the comfortable and convenient urban lifestyle. Positive interactions are also beneficial for kangaroos, such as the provisions of forage and cover (Coulson et al., 2014). Human and kangaroo interactions can be important for the local economy of coastal towns, attracting both national and global tourists. For example, Anglesea promotes "where bush meets the sea" and the local golf club allows visitors to play golf amongst resident kangaroos (Inwood et al., 2008). The importance of kangaroos in tourism is outlined in a research by Higginbottom et al. (2004). This study showed that while kangaroo ecotourism provides many benefits to Australia's economy and image, it may also result in negative outcomes from inappropriate interactions if poorly managed.

2.4.2 Negative outcomes

Kangaroos in per-urban areas will generally be seen as problematic only when their presence conflicts with human interests or safety (Ballard, 2006). There are several outcomes from negative interactions between humans and kangaroos which include injury or mortality, property damage and the reduction in quality of life (ACT Kangaroo Management Plan, 2010).

Aggression

Intra-specific aggressive behaviour has been well studied among kangaroos (Croft, 1985; Ganslosser, 1989). However, inter-specific aggression has also known to occur in certain situations. There are reports of kangaroos expressing self-defense behaviours when threatened by wild dogs (Wright, 1993). Kangaroo aggression is of most concern when directed towards domestic animals, and in extreme cases, humans (Ballard, 2006). Reports of kangaroo attacks are uncommon and usually result in only minor injuries to people. However, they receive significant media attention when they do occur, especially if it is severe. For example, in 1996, a 13 year old boy received severe facial wounds when attacked by a large kangaroo on a golf course in Grafton, NSW, sparking significant media interest (Ballard, 2006). Three recent examples summarized in Table 2.5 show that aggressive behaviour is not necessarily restricted by the kangaroo's age or sex. Aggression is also not exclusively shown from kangaroos, but can also emanate from humans. Table 2.6 summarizes various recent media reports of kangaroo related attacks along the Coffs Coast, including attacks by people on kangaroos.

Table 2.5. Recent examples of eastern grey kangaroo (*Macropus giganteus*) attacks on humans, reported in the media (excluding attacks reported from the Coffs Coast).

Kangaroo	**Victim**	**Injury**	**Location**	**Report**
Juvenile	Seven year old girl	Moderate scratches and bruising	Wyangala (near Cowra), NSW	(Morton, 2012)
Female with young-at-foot	Elderly lady	Major cuts and bruising	Sunshine Coast, QLD	(Sundstrom, 2015)
Large adult male	Elderly man	Major cuts and deep gashes	Torbanlea (near Hervey Bay), QLD	(Martin, 2012)

Table 2.6. A summary of recent local media reports of attacks both by kangaroos and on kangaroos along the Coffs Coast.

Victim	Location	Injury	Report
Young boy	Heritage Park estate	Major cuts on victims back	Coffs Coast Advocate (Singleton, 2014)
Young boy	South Grafton	Major gash with scratches	Coffs Coast Advocate (Howard, 2013)
Elderly man	Woolgoolga	Minor head wounds from being knocked down	Coffs Coast Advocate (Thandi, 2014)
Teenage girl	Avocado Heights	Multiple gashes	Coffs Coast Advocate (McDougal, 2006)
Multiple kangaroos	Emerald Heights	Beheading	Local ABC (Poole, 2011)
Multiple kangaroos	Heritage Park estate	Vehicle hit and run	Coffs Coast Advocate (Barwell, 2015)

Property damage

Ballard (2006) outlines the impact of peri-urban kangaroo populations on residential properties. Kangaroos can frequently be found grazing and resting on residential lawns. Lawn grazing may not be seen as a problem as they tend to avoid reducing it to soil (Ballard, 2006). However, a kangaroo's presence may cause physical damage to gardens, fences or other parts of the property (Temby, 2003). Damage can occur when males are fighting or through their movements, such as when they are startled (Ballard, 2006).

Vehicle incidents

Vehicle collisions with wildlife are a common occurrence in urban areas, especially involving large herbivore species such as deer (Moriarty, 2004) and kangaroos (Inwood et al., 2008). Roads and highways can form barriers between kangaroo populations and resources, particularly in urban areas where space is already limited and movement is restricted by properties (Ramp and Ben-Ami, 2006). This, along with increases in kangaroo densities and human traffic, results in a heightened risk of injury or mortality in human-kangaroo vehicle incidents. A study by Inwood et al. (2008) indicated an increase in kangaroo road kills in Anglesea from 1997 to 2006, with residents believing that they might hit a kangaroo at any time whilst driving.

2.5 Managing kangaroos in peri-urban areas

Kangaroo management is typically required in urban areas when populations are abundant, or perceived as overabundant and therefore believed to be the cause of kangaroo related problems (Coulson, 2007). The management of kangaroos can be a contentious issue as kangaroos are a highly valued native animal and a national icon (Coulson, 1998). This places constraints on the management of kangaroos which can become challenging for managers and wildlife agencies when deciding on appropriate management strategies (Herbert, 2004).

2.5.1 Overabundant populations

Australia faces an incredible number of management challenges imposed by overabundant exotic mammal species such as foxes, cats, camels and horses (McLeod, 2004). However, some areas of Australia are also impacted by the overabundance of native species (Lunney et al., 2007). Parallels exist between kangaroos in Australia and deer in North America, where hunting restrictions and the removal of predators have resulted in overabundant herbivore populations which impact vegetation structure and biodiversity (Dexter et al., 2013). The koala (*Phascolarctos cinereus*) is another example of an overabundant native Australian species. While threatened in parts of mainland Australia, they are overabundant on Kangaroo Island on the coast of South Australia (Molsher, 2015). Duka and Masters (2005) outline the impacts of koalas living in high densities and the social issues surrounding the management of the species due to their iconic value, which is a similar scenario facing kangaroos (Coulson, 1998).

In urban areas, kangaroo populations may be classified as overabundant when negative effects on human lifestyles become frequent (Herbert, 2004). In rural lands, kangaroos are instead considered overabundant when their numbers begin to have severe impacts on their own welfare, as well as the environment through overgrazing (Coulson, 2001). For peri-urban populations, overabundance is not necessarily an indication of high kangaroo densities, but rather a perception of high densities influenced by frequent interactions. Habitat fragmentation and restriction of kangaroos range caused by urban barriers such as fencing, roads and buildings, typically leads to these frequent interactions within the peri-urban environment (Herbert, 2007). Coulson (2007) noted that kangaroo overabundance is too often seen as the problem rather than the cause of the problem. He argues that if a high density of kangaroos is viewed as the problem, managers might cull the population and deem the program a success. However this only results in a smaller population while the potential for kangaroo related issues still remains. When this view is applied to urban kangaroo management, it can become clear

that population control only manages the cause of kangaroo problems rather than the problem itself. Therefore, additional management strategies are needed to manage the associated problems of high kangaroo densities in urban areas.

2.5.2 Management options for population control

Realistic and socially acceptable control methods are required when kangaroo populations attain high densities in and around peri-urban areas and create conflict with humans. For high density kangaroo populations, three primary control methods currently exist.

Lethal removal (culling)

Shooting is generally recognized to be the most effective and economically viable way to reduce a population to manageable numbers (Olsen and Low, 2006). It is a common control method for kangaroos in rural areas where hundreds of thousands are culled yearly for harvesting and to reduce conflict with primary produces (Herbert et al., 2010). However, in urban areas shooting is seen as socially unacceptable and poses a serious risk to human safety (Herbert et al., 2010). The culling of kangaroos can receive significant nation and global media attention (e.g. Linden 2005) and is often targeted by animal rights protestors (Stacker, 2005). Capture and lethal injection is an alternative method to shooting which can be suitable for peri-urban kangaroo populations. However, this method is expensive and socially unacceptable if performed close to the public eye (Herbert et al., 2010). Ballard (2008) surveyed residents in Port Macquarie regarding local kangaroos with feedback showing a clear dislike for the culling of aggressive kangaroos. Studies on urban deer management in North America also found that lethal control methods are ill-favored by local communities who prefer non-lethal control methods such as translocation (Stout et al., 1997).

Translocation

Relocating overabundant or problematic animals is often a socially acceptable method. However, in many scenarios, this is not realistic (Ballard, 2008). Translocation is usually carried out for conservation purposes on rare or threatened species (Fischer and Lindenmayer, 2000). Higginbottom and Page (2010) assessed the translocation of eastern grey kangaroos at the Gold Coast in Queensland. In their study, translocation proved successful in the short-term but concluded that it was not ideal due to time and money constraints, especially for large populations. Translocating problem urban wildlife is generally not supported due to animal welfare considerations (ACT Kangaroo Management Plan, 2010).

Fertility control

Fertility control is receiving significant attention as a suitable, non-lethal population control method (Wilson et al., 2013). Extensive research overseas has been directed towards the development and assessment of various contraceptive technologies (Fagerstone et al., 2010). For example, Conner et al. (2006) assessed fertility control in overabundant elk populations in North America. Their study confirmed its effectiveness, but noted that practical application is limited by treatment duration and required females to be treated before the breeding season.

The aim of fertility control is to reduce the population growth, decreasing the need for lethal interventions and reducing animal welfare and ethical concerns (Herbert et al., 2010). The usefulness of fertility control is dependent on the ease of delivery, the duration of the effect and the absence of harmful effects (DeNicola et al., 1997). Three potential fertility control techniques were reviewed by Herbert (2004), outlining the advantages and disadvantages of fertility control of kangaroos in different scenarios. In recent years there have been substantial technological advances in contraceptive methods of kangaroo population control due to the changing social ethic towards management, especially in urban areas (Herbert et al., 2010). Herbert et al. (2010) suggests that long-term fertility control can be achieved in eastern grey kangaroos using contraceptive implants containing either Suprelorin or Levonorgestrel. The suitability of fertility control in urban kangaroo populations was highlighted in a study by Wilson et al. (2013). Their research included the monitoring of deslorelin implants in female eastern grey kangaroos at the Anglesea golf course. The implants successfully reduced fertility over three successive breeding seasons. Continual fertility control required females to be re-treated, which was achievable in urban areas where kangaroos are easy to approach, capture and monitor (Herbert et al., 2010).

Decision analysis

In deciding what control options are suitable, managers need to examine the biological, economic, social and political considerations for each option (Fryxell et al., 2014). The appropriateness of each option is also dependent on the context of the management scenario. Multiple control options may be feasible in some situations while other situations may hold no valid option. The feasibility and acceptability of various control options for kangaroos in urban areas, in the context of the Coffs Harbour Northern Beaches, is summarized in a decision analysis matrix table (Table 2.7).

Table 2.7. Decision matrix analysis examining potential control options against a criteria of feasibility for managing high density peri-urban kangaroo populations on the Coffs Harbour Northern Beaches.
1, yes; 0, no; ?, unsure. For each control option, a '0' precludes any further consideration of that option.

Control options	Technically possible	Practically feasible	Economically desirable	Environmentally acceptable	Politically advantageous	Socially acceptable
Do nothing	1	0				
Shoot	1	1	?	1	0	
Lethal injection	1	1	1	1	?	0
Relocation	1	1	?	?	1	1
Fertility control	1	1	1	1	1	?
Introduce diseases	1	?	?	0		
Introduce predators	1	?	?	0		

This decision matrix analysis reveals that out of the potential control options only a few options can be considered. The option 'do nothing' would not be practical in the context of the Coffs Harbour Northern Beaches as conflict between humans and kangaroos are only going to increase with urban expansion. While options such as 'introduce disease' or 'introduce predators' are technically possible, they may not be practical or economical, and certainly not environmentally acceptable (as they may impact on other species). 'Shooting' may be a viable option in rural areas. However, it would not be politically advantageous for urban locations due to its controversial nature. The alternative cull option of a 'lethal injection' may also fail the 'politically advantageous' criteria and would be socially unacceptable in the Coffs Harbour Northern Beaches context. 'Relocation' may be widely accepted socially and politically. However, its feasibility for the economy and environment is uncertain. In this scenario, 'fertility control' would be the most appropriate option, assuming that the local communities' opinion on it as a control method is positive.

2.5.3 Management strategies to reduce negative interactions

The control of urban kangaroo populations can reduce the likelihood of human-kangaroo encounters, but it does not remove the potential for negative outcomes when encounters do occur. To manage urban wildlife conflict, additional strategies are required to resolve conflicts and ensure that interactions remain positive. Various management strategies to reduce negative interactions and promote positive interactions are outlined below.

Vehicle incident mitigation

Vehicle related incidents with kangaroos are a significant management issue which impacts both human and kangaroo welfare (Coulson et al., 2014). Two strategies of mitigation include modifying the kangaroo's behaviour through certain road attributes and modifying the behaviour of drivers (Table 2.8). Studies on these strategies generally suggest that modifying the animals behavior is more effective than modifying driver behaviour (Dique et al. (2003).

Table 2.8. Examples of management strategies to reduce kangaroo related vehicle incidents.

Mitigation strategies	**Examples**
1) Road alterations to modify kangaroo behaviour	*Roadside fencing* – Limits kangaroo access to roads (especially highways) and can assist in guiding animals to nearby underpasses (Chachelle et al., 2016) *Underpasses* – Allow for habitat connectivity and safer movements. Magnus et al. (2004) suggests that larger animals such as kangaroos prefer short and wide underpasses which have a clear line of sight to the other side. *Repellents* – Ramp and Croft (2002) have had some success trailling the use of odours (which mimic canine urine) to repel macropodids. Roadside lighting has also been suggested to deter macropodids from roads because of the increased visibility to predators (Magnus et al., 2004).
2) Modifying human driver behaviour	*Wildlife signs* – Signs depicting animals or warning signs. Studies by Coulson (1982) and Dique et al. (2003) concluded that signs where inadequate in reducing vehicle speeds and mortality of kangaroos and koalas, respectively. *Speed limit reduction* – May not be feasible for highways but can be effective for town and street roads (ACT Kangaroo Management Plan, 2010).

Property fencing

Residents may erect fences to protect themselves, their pets or their garden from kangaroos (Ballard, 2006). Fencing may include full property fencing which completely exclude kangaroos, or partial fencing to exclude kangaroos from certain parts of the property such as gardens or backyards (Ballard, 2006). Fencing can provide a sense of security and reduce negative interactions. However, fencing may cause problems such as movement restriction for kangaroos which may be forced to use roads and confine their numbers to un-fenced properties (Chachelle et al., 2016). Furthermore, fencing can cause welfare impacts on kangaroos which may injure themselves or get trapped in fences (Ballard, 2006). In peri-urban areas, fencing is seen as an adequate management strategy, providing kangaroos still have sufficient space to move between and around properties. However, residents may see property fencing as unsightly and would rather prefer suitable alternatives to manage conflicts.

Education

Educational programs in schools, or information provided through pamphlets and various media including radio, television and the internet, provide a way to raise awareness on how to interact appropriately with kangaroos. For example, the 'Living with kangaroos' pamphlet (Office of Environment & Heritage, 2011) was made available to the public to provide information on kangaroo habitat needs and behaviour and what to do if confronted by an aggressive kangaroo. This pamphlet was originally part of a campaign to raise awareness of kangaroo related issues, which included a series of school visits in South Grafton by a local NPWS ranger (Office of Environment & Heritage, 2011).

Education is important as residents may also be inadequately informed about the efficacy of different management strategies. For example, a study on urban deer management in North America by Lauber and Knuth (2004) found that citizens changed their attitudes about contraception as a management option after receiving relevant information on its effectiveness and humaneness in urban wildlife management. Improved education has an important role in preventing rash management decisions in the case of an aggressive animal (Soulsbury and White, 2015). Better education can also improve the community's values and perceptions of urban wildlife (Caula et al., 2009).

2.5.4 Kangaroo management plans

Management plans are typically prepared for overabundant kangaroo populations (ACT Kangaroo Management Plan, 2010). Because every kangaroo population will be different; management programs need to identify the key, underlying kangaroo related problems that occur or are expected to occur at the management site, and then set clear management objectives (Coulson, 2007). Kangaroo management plans and programs incorporate various stakeholders and agencies related to the management context to best formulate a plan and evaluate appropriate management options (Inwood et al., 2008). The following two case studies outline scenarios where a kangaroo management plan has been developed to manage peri-urban kangaroo populations and their interactions with human residents.

Case Study: ACT Kangaroo Management Plan 2010

Free ranging kangaroo populations are a significant component of the 'bush capital' image of the Australian Capital Territory (ACT). The sympatric occurrence of humans and kangaroos in the ACT has resulted in high community interest towards kangaroos and kangaroo management. Kangaroo management is highly controversial in the ACT due to the close proximity of the public to commercial harvesting and population control of kangaroos (Hampton and Forsyth, 2016). In 2008, a survey was conducted by Micromex Research to gain an understanding of the attitudes of ACT residents towards kangaroos and kangaroo management. The results of the survey assisted in the development of the management plan and associated management strategies. The ACT kangaroo management plan aims to maintain kangaroo populations as a significant part of the local fauna and an integral component of grassy ecosystems. The plan is also focused on managing and minimising the social, economic and environmental impacts of kangaroos on humans and ecosystems within the ACT.

Case Study: Community based kangaroo management plan for Anglesea, Victoria

Anglesea has been the focus of several studies on overabundant urban kangaroo populations in the last 15 years (Coulson, 2007; Inwood et al., 2008; Coulson et al., 2014). The small coastal town is located in southern Victoria and supports a population of approximately 2,000 permanent residents and up to 10,000 summer residents. Kangaroo populations here are the subject of a community based management program developed to address kangaroo related issues (Inwood et al 2008). Inwood et al. (2008) reported on local kangaroo populations, analyses of road-kill data for the area and the formation of a Kangaroo Advisory Group for Anglesea. Their study suggested that the Anglesea golf course formed the nucleus of the

kangaroo population, supporting a high density of kangaroos. Road kills were also considered by residents to have increased over the last decade. Key issues emerged, which included: understanding Anglesea's kangaroos; monitoring these populations (specifically on the golf course); minimising vehicle incidents and conflict; and managing sick and injured kangaroos.

Community perspectives in kangaroo management

The positive and negative interactions people have with urban wildlife heavily influence their perception and attitudes towards them (Henderson et al., 2000). In North America, researchers have used public involvement through community surveys to assist in developing acceptable management strategies for urban white-tail deer (Stout et al., 1997) and elk (Lee and Miller, 2003) populations. In Australia, similar research has been conducted on urban brush turkeys (*Alectura lathami*) (Thomas and Jones, 1997). Ballard (2008) investigated peri-urban kangaroo management preferences of residents in several areas along Australia's north-east coast through community surveys. Residents that frequently share the peri-urban environment with kangaroos can accumulate a large amount of information on local kangaroo populations, both intentionally and unintentionally through their interactions (Ballard, 2008). Furthermore, community perspectives, attitudes and experiences with kangaroo interactions can be extremely useful for mangers in making management based decisions (Ballard, 2006).

Case Study: Community attitudes towards kangaroos in Port Macquarie

Ballard (2008) researched community attitudes towards local kangaroo populations at the Retreat Village in Port Macquarie, NSW. After two incidents of aggression by kangaroos towards elderly residents, the Retreat Village retirement community called for a cull of local kangaroo populations. Fearing public backlash, wildlife authorities decided to further assess the human dimensions to management options. Ballard's study involved the Retreat Village community of about 200 residents in the decision making of management options. His study had a participation rate of 91% and results identified the social perspectives of appropriate management options for the area. Residents did not welcome the culling of aggressive kangaroos. However, there was a strong preference for proactive management strategies such as education or relocation.

Ballard's (2008) case study emphasized the difficulties in urban kangaroo management. Although the majority of respondents believed that information on how to live with kangaroos should be provided, only a third of the Retreat Village residents had received suitable information, identifying a clear lack in educational efforts. Relocation, which was favoured by

over half of the residents, was difficult to implement due to the economic constraints of capturing and moving the animals. This study however, managed to highlight the importance of community feedback for management authorities and their decisions for minimising kangaroo related problems.

Aboriginal perspectives on kangaroo management

When engaging the public for management-based decision making, it is important to include a variety of cultural perspectives, especially that of indigenous Australians (Dawson, 1998). Aboriginals, both past and present, value kangaroos as they are often culturally, socially and spiritually significant to them (Thomsen et al., 2006). The unique depth of environmental understanding held by traditional owners can be a valuable part of kangaroo management (Berkes, 1999). The interests and perspectives of Aboriginal people are, however, sometimes not understood by stakeholders or managers due to the lack of inclusion in management development (Thomsen et al., 2006). Thomsen et al. (2006) consulted traditional owners from two different cultural regions for their perspectives and attitudes towards kangaroo management and commercial harvesting. Their research resulted in a diversity of views, highlighting the challenge, but also the importance of Aboriginal involvement in decision making for kangaroo management.

2.5.5 Management priorities and objectives

When setting management objectives, management programs need to begin by identifying current or expected kangaroo related problems and understanding the contributing factors to these problems (Coulson, 2007). Furthermore, understanding the ecology of the kangaroo population to be managed is an integral part when setting management plans. For example, Coulson et al. (2014) suggests that kangaroos in Anglesea have retained their mating system in the urban area, moving throughout Anglesea during Autumn and Winter which increases their exposure to vehicle incidents. This behaviour of males is important to consider when attempting to identify hotspots and mitigate vehicle collisions with large males.

There are numerous challenges managers face when deciding on management priorities and objects. These include: determining if a population is overabundant, if or when to intervene, setting realistic target densities, and how to control populations through socially acceptable, logistical and cost-effective means (Herbert, 2007). Managers also need to monitor the success of programs relative to its objectives (Herbert, 2007). It is important for wildlife agencies to engage the community and promote education about urban kangaroos and the risks

involved with interactions (Soulsbury and White, 2015). There is also a need to raise awareness of the benefits associated with living with kangaroos, thereby shifting from seeing them as a problem, to viewing them as an integral part of the peri-urban ecosystem (Soulsbury and White, 2015). It is also important to educate people on how to appropriately deal with sick or injured animals and know who to call (e.g. WIRES and/or NPWS). Overall, it is evident that managers need to look at how to maximize the benefits that human kangaroo interactions bring and also manage the increased accessibility of natural greenspaces to urban wildlife.

Chapter 3: Kangaroo populations in the Coffs Harbour Northern Beaches region

3.1 Introduction

Understanding species abundance and population trends is vital for effective wildlife management (Fryxell et al., 2014). The eastern grey kangaroo often reaches densities that are considered high when they begin to impact on other species or themselves (Coulson, 2007; Howland et al., 2014). The ACT Kangaroo Advisory Committee (1996) reported high densities of kangaroos in nature reserves in the ACT, where densities were on average 2.3 kangaroos per hectare. Various other studies have reported on high eastern grey kangaroo densities in woodland and grasslands, and their impacts on local ecosystems (Fletcher, 2006; Howland et al., 2014). In regards to peri-urban kangaroo populations, Coulson et al. (2014) believed that kangaroo densities can be enhanced by the urban environment, as it has in Florida key deer (*Odocoileus virginianus clavium*) populations (Harveson et al., 2007). Anglesea in Victoria provides the only example where coastal peri-urban kangaroo densities have been studied (Coulson et al., 2014).

Surveying kangaroos in peri-urban areas can be challenging due to limitations placed by properties and their influence on species distribution and detectability. Kangaroo distribution in a peri-urban area is usually associated with the location of accessible green spaces (Coulson et al., 2014). This often results in kangaroos occurring in areas such as backyards or behind properties, making detection difficult during population surveys.

Direct observation counts can be a simple and cost effective method of estimating kangaroo abundance in peri-urban areas (Coulson et al., 2014). However, unless all kangaroos are able to be detected with relative confidence, it is likely to result in an under-estimation of the total population (Witmer, 2005). In situations where detection of all animals is limited, alternative methods can be used.

One widely used technique to survey wildlife populations is distance sampling, which can return accurate estimates, providing appropriate methods are used and assumptions are not violated (Buckland et al., 2001). Distance sampling is most commonly undertaken with line-transects. This involves an observer moving along a transect line, recording perpendicular distances to detected objects (e.g. animals), or clusters of objects of interest (Buckland et al.,

2001). This method of sampling relies on several assumptions which are essential for reliable estimates: (1) all objects on the line are detected, (2) measurements are taken to where the objects were initially detected, and (3) distance is measured accurately. (Buckland et al., 2001). The closer animals are to the transect line, the more likely they are to be detected. Animals that are missed during sampling are estimated from a detection probability model, to give an estimated animal density for the area of study (Buckland et al., 2001). Distance sampling by line transect has been proven to be a suitable method for estimating abundance of free-ranging eastern grey kangaroos (Glass et al., 2015). However, its appropriateness in sampling peri-urban populations is unknown.

Two of the core aims of the Coffs Harbour Northern Beaches Kangaroo Management Plan include the continuation of a sustainable kangaroo population as well as a better understanding of the kangaroo population demographics in the Coffs Coast region. Anecdotal observations by local residents suggest that kangaroo numbers have been increasing in the last decade. The NPWS have been conducting kangaroo counts at Heritage Park since 2007, and noted an increase in their abundance (Dave Scotts, NPWS/CHCC, pers. comm). However, there no current records of kangaroo abundance elsewhere in the Coffs Harbour Northern Beaches region. The aim of this chapter is to provide new and detailed information on kangaroo population dynamics at four 'kangaroo hotspot' locations along the Coffs Harbour Northern Beaches.

3.2 Methods

3.2.1 Study areas

This study was conducted at four 'kangaroo hotspot' locations on the Coffs Harbour Northern Beaches. The entirety of Heritage Park (Figure 3.1) and Avocado Heights (Figure 3.2) was included in the surveys, while only the headlands of Emerald Beach (Figure 3.3) and the golf course at Safety Beach (Figure 3.4) were surveyed. The size of the area surveyed for the Emerald Beach headlands (LAMN and Dammerels) and the Safety Beach golf course was 23 hectares and 47 hectares, respectively.

These four sites provided unique examples of several peri-urban environments, which kangaroos utilized in various ways. For example, populations were concentrated on residential lawns and vacant blocks at Heritage Park and Avocado Heights, while populations at Emerald Beach and Safety Beach were concentrated in areas of suitable natural environment adjacent to the residential areas.

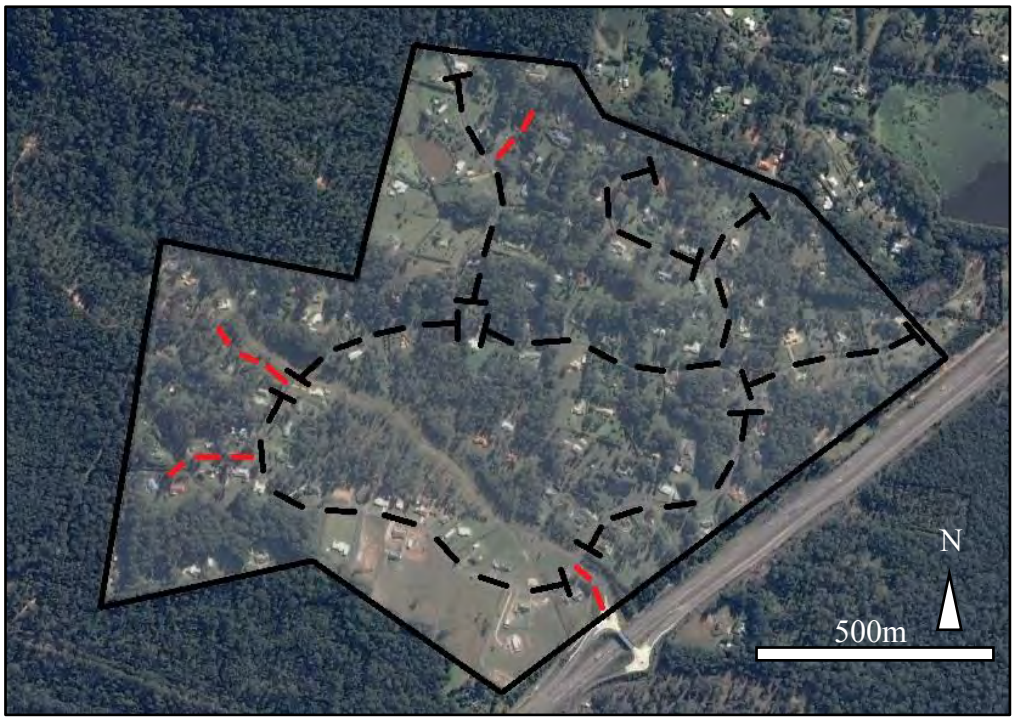

Figure 3.1. Satellite image of Heritage Park, located on the Coffs Harbour Northern Beaches, NSW. The solid black line indicates the study area boundary, the dashed black lines are the transects (streets) used during distance sampling, and the dashed red lines indicate additional streets used for direct observation counts.

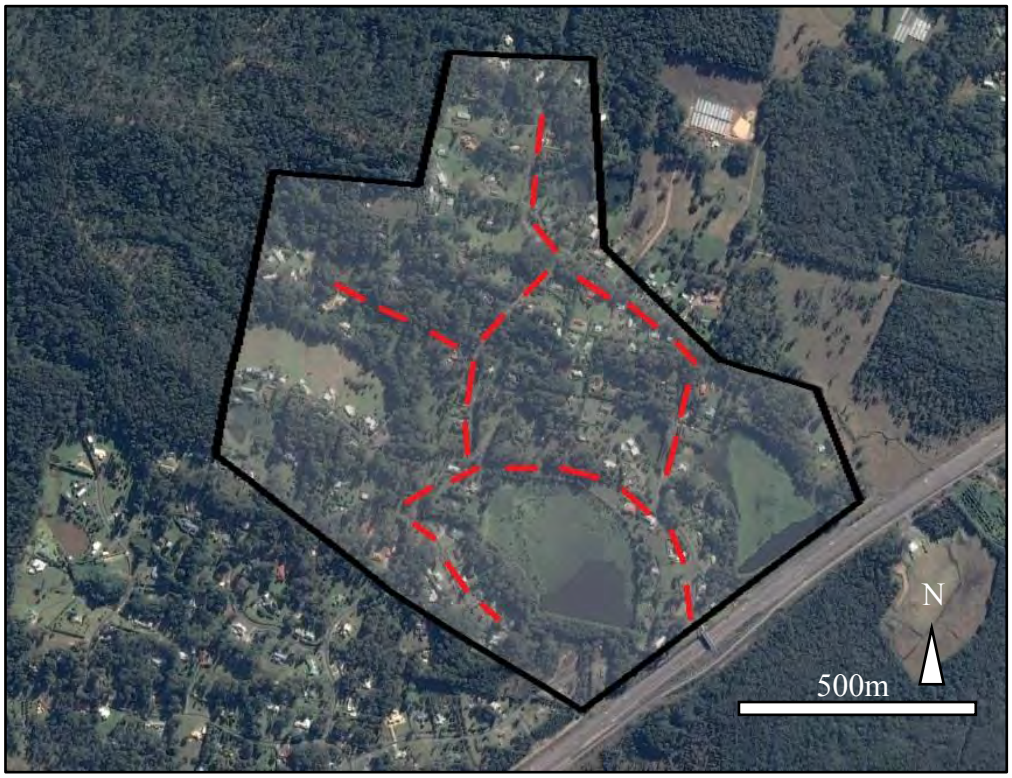

Figure 3.2. Satellite image of Avocado Heights, located on the Coffs Harbour Northern Beaches, NSW. The solid black line indicates the study area boundary, and the dashed red lines indicate streets used for direct observation counts.

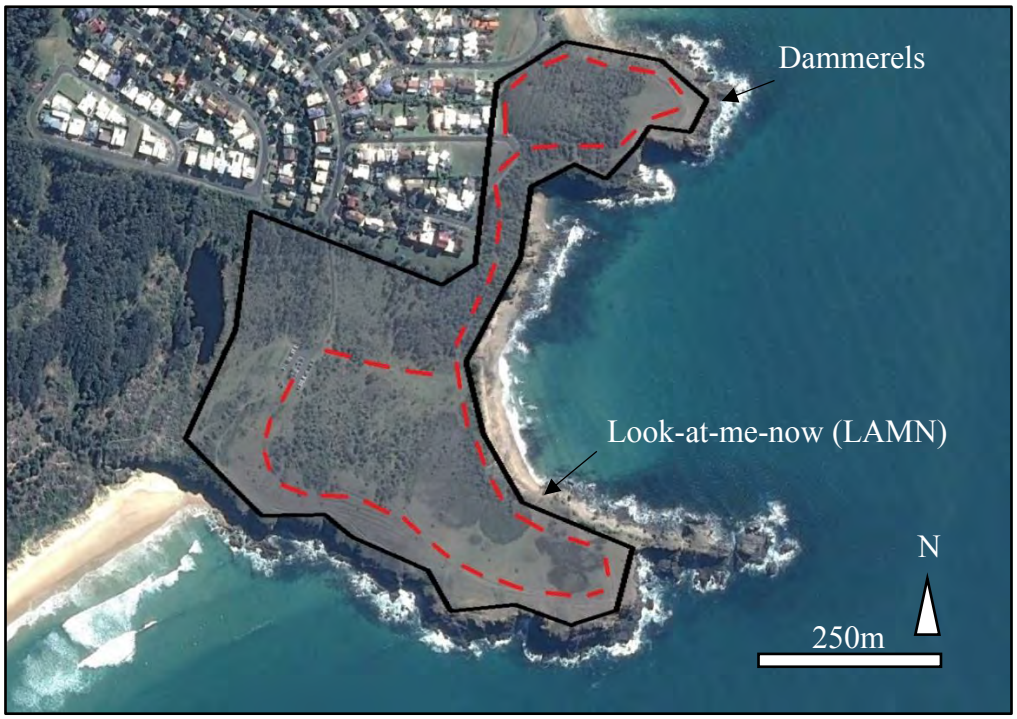

Figure 3.3. Satellite image of the Emerald Beach headlands, located on the Coffs Harbour Northern Beaches, NSW. The solid black line indicates the study area boundary, and the dashed red line indicates the approximate path walked for direct observation counts.

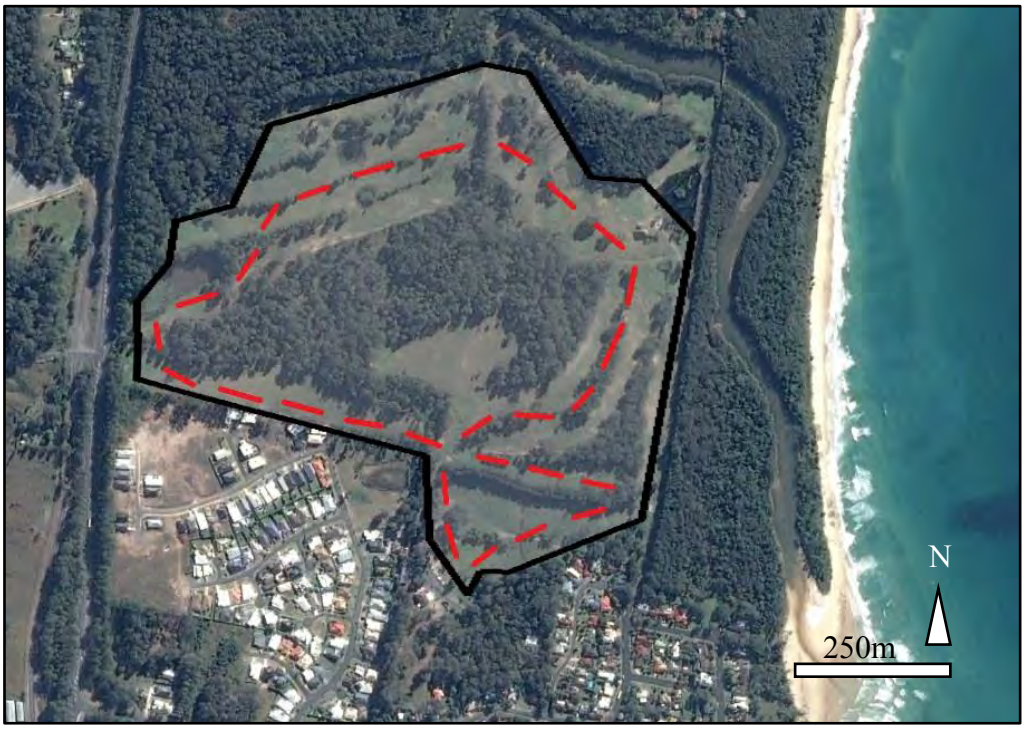

Figure 3.4. Satellite image of the Safety Beach 18-hole golf course, located on the Coffs Harbour Northern Beaches, NSW. The solid black line indicates the study area boundary, and the dashed red line indicates the approximate path walked for direct observation counts.

3.2.2 Study timing and approach

This study was conducted between December 2015 and October 2016. I began with a trial count for each site in December 2015, to determine sampling procedure. Formal counts began in February 2016 and were undertaken every two months (April, June, August) until the final counts in October 2016. During each sampled month, two observers would count eastern grey kangaroos four times at each site; once in the morning and once in the evening, repeated the following day. However, due to a variety of circumstances such as rain or light constraints (especially in winter), some sites were counted on subsequent days or unfortunately missed. Morning counts commenced shortly after sunrise and started at the Safety Beach golf course, followed by the Emerald Beach headlands, Heritage Park and Avocado Heights. The survey team would then conduct evening counts in reverse order and aim to finish by sunset. The golf course was counted first and last to avoid counting while the course was being used by golfers. It took approximately 2-3 hours to collectively count kangaroos at all four sites.

3.2.3 Distance sampling by line-transects

I originally trialed distance sampling by line-transect at each site in an attempt to achieve density estimates. However, these trials proved this method to be unsuitable for Avocado Heights, Emerald Beach and the Safety Beach golf course. The primary concern for Avocado Heights were the inconsistencies in the layout of the site, which included various small lakes, ponds and steep inclines. The population size was also too small to generate an accurate kangaroo population estimate with the number of clusters per sampling period falling well below the recommended 60-80 observations by Buckland et al. (2001). For the Emerald Beach headlands and the Safety Beach golf course, I decided that direct observation counts would be sufficient due to the small area of the site and the confidence that the vast majority of kangaroos could be detected.

Distance sampling by line-transect was conducted simultaneously during direct kangaroo counts at Heritage Park. Line-transects were placed systematically to utilize streets (Figure 3.1). Distances were only recorded for animals along these transects and any animals observed outside of these transects were included in the direct observation counts. Perpendicular distances were determined using a Nikon Aculon 6x20 Laser Rangefinder (Lidcombe, NSW). Measurements were taken to the approximate middle of a cluster of kangaroos, or directly to a solitary animal. Clusters were defined as a group of individuals within five metres from one another.

3.2.4 Direct observation counts

Direct observation counts were conducted using vehicle and foot transects, which included roads, walking tracks or fairways. These counts provided an estimate of kangaroo abundance for each site as the 'minimum number known to be alive' (referred to as 'MNKA') for that sampling period (Sutherland, 2006). This implied that for each sampled month, the largest count was assumed to be the minimum number of individuals present at that site. Counts were tallied by a primary observer, with a secondary observer pointing out any animals that may have been missed and assisting in categorizing each animal. The assessed categories included; 'Large Male', 'Female with joey' (with obvious pouched or temporarily at-foot joey), 'Other' to denote sub-adults, 'Young-at-foot' (appearing to be independent from a pouch) and 'Unknown' (any animal that could not be clearly identified). Care was taken by each observer to avoid recounting animals during each survey.

Sites varied greatly in size and characteristics, and therefore, different methods of traversing were used when sampling each site:

(1) Heritage Park/Avocado Heights – A vehicle was used to traverse streets/roads to attempt to cover as much of the site as possible, without impacting residents' privacy. In this method, the passenger was the primary observer and recorder, with the driver assisting in counting kangaroos on the driver's side. The car travelled slowly (< 10 km/h) to minimize disturbance and ensure the greatest detectability of animals. When kangaroos were encountered, the driver would pull over to allow the observer to count and categorize each individual. Binoculars were occasionally used when counting kangaroos at a distance.

(2) Emerald Beach - The headlands were surveyed on foot by closely following a walking track which connected the two headlands. Observers walked slowly to ensure that all kangaroos were counted and to minimize disturbance. However, on some occasions, kangaroos occupying areas of dense vegetation were difficult to categorize, resulting in an observer 'clapping hands' to alert kangaroos.

(3) Safety Beach golf course – To ensure the maximum visibility and detection of kangaroos, counts were conducted on the golf course by either walking down the centre of a fairway, or the edge of the middle fairway when several other fairways were adjacent. Binoculars were used when necessary to count and identify distant animals. Care was taken to avoid disturbing animals or any patrons using the golf course.

3.2.5 Data analysis

Using R studio (Version 0.99.903), a paired t-test was conducted to determine any significant differences between morning and evening counts at each site. While I was primarily concerned with the largest direct observation count (i.e. the MNKA) for each sample month, I also included the range of highest to lowest counts to give an indication of precision. Perpendicular distance data was analysed in R studio, using the package 'Distance' (Version 0.9.6) (Miller, 2015). I decided to not truncate my data as exploratory analyses revealed no obvious outliers in the dataset (i.e. no long tail in the detection function; Buckland et al. (2001)). I ran three detection function models for each month: half-normal key with cosine adjustments; uniform key with cosine adjustments; and hazard-rate key with polynomial adjustments. I used Akaike's Information Criterion (AIC) to select the best model, which was also aided by visualizing of the model to judge the detection of probability near the line (Buckland et al., 2001). The hazard-rate detection function model was selected for all months except October, where the uniform with cosine model was selected.

3.3 Results

There was no significant difference between morning and evening counts for each site (Heritage Park, $d.f. = 9$, $P = 0.967$; Avocado Heights, $d.f. = 7$, $P = 0.056$; Emerald Beach headlands, $d.f. = 7$, $P = 0.696$; Safety Beach golf course $d.f. = 7$, $P = 0.127$). As such, both morning and evening counts were combined as replicate samples for each surveyed month.

3.3.1 Density estimates

Kangaroo density (per hectare, ha^{-1}) estimates at Heritage Park, calculated from distance sampling, decreased from 1.78 ha^{-1} (95% Confidence Interval [CI] 1.14 – 2.78) in February to 1.57 ha^{-1} (95% CI 1.60 – 2.32) in April. There was a slight increase in the June and August estimates, with October recording the highest density of kangaroos at 1.99 ha^{-1} (95% CI 1.56 – 2.55) (Figure 3.5). There was a dissimilar trend of density estimates throughout the year between distance sampling and MNKA counts (converted into density by dividing by the area of the site) for Heritage Park (Figure 3.5). Density estimates from the MNKA increased from February to April, followed by a decline in June and August (Figure 3.5). Density from MNKA counts consistently remained below each corresponding month's distance sampling estimate, following the prediction that distance sampling method accounts for undetected individuals.

Kangaroo density was also determined at the other three sites from the MNKA as stipulated above. Densities at Avocado Heights ranged from 0.28 ha^{-1} in April to 0.35 ha^{-1} in June (Figure 3.6). Emerald Beach headlands reached 4.87 ha^{-1} in April, with August recording a low of 2.26 ha^{-1} (Figure 3.6). Kangaroo density at the Safety Beach golf course ranged from 1.57 ha^{-1} in June to 2.32 ha^{-1} in October (Figure 3.6).

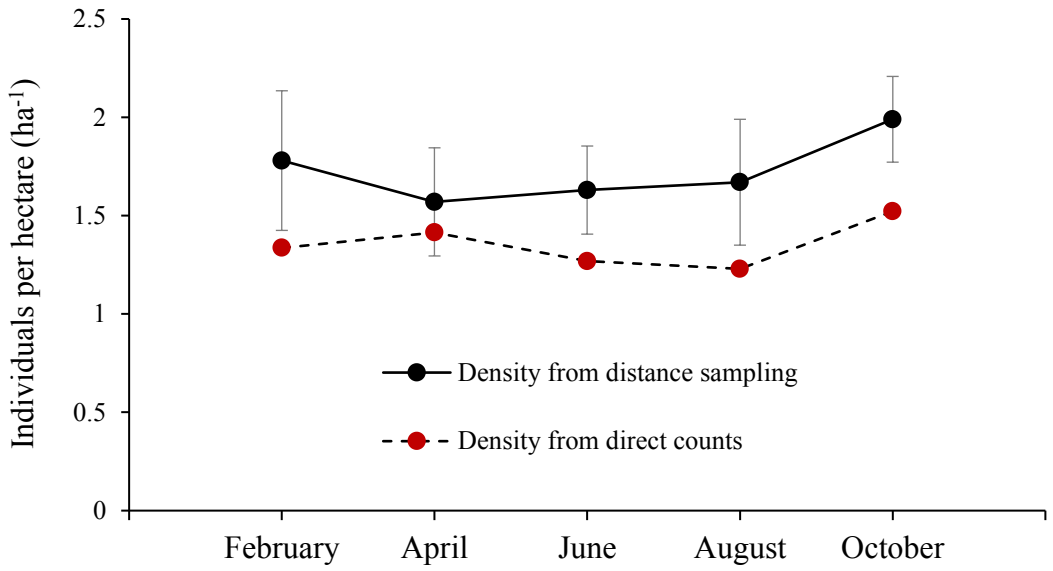

Figure 3.5. Density estimates for kangaroos at Heritage Park, calculated from distance sampling and MNKA counts for each sampled month during 2016. Density is recorded in ha^{-1}; error bars indicate the standard error for distance sampling density estimates.

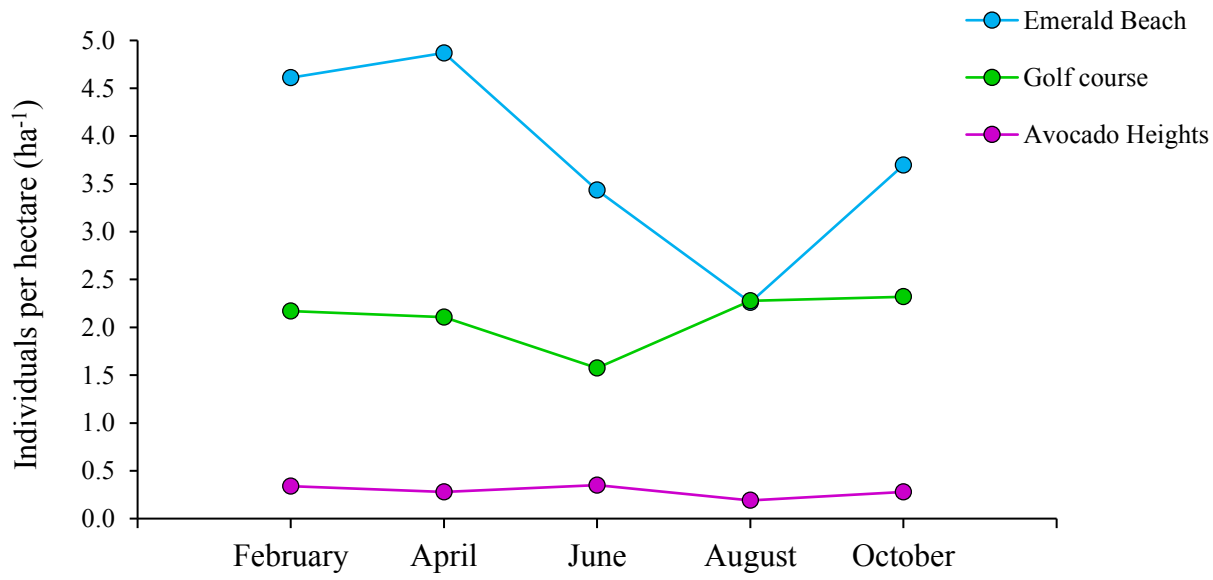

Figure 3.6. Density of kangaroos at each site for each sampled month during 2016. Density was determined using the MNKA divided by the size of the study area, in hectares.

3.3.2 Minimum number known to be alive (MNKA)

Heritage Park

Kangaroo MNKA was stable between 250 and 300 individuals throughout most of the year, however exceeded 300 individuals only in October (Table 3.1). There was a small decline in MNKA from April to August; these months also had the largest differences between the minimum and maximum counted (Table 3.1). 'Large males' consistently made up between 7-13% of the kangaroo MNKA for each month (Figure 3.7). There was a low proportion of 'females with joeys' in February (3% of the MNKA), which increased in August (7% of the MNKA) and peaked at 17% of the MNKA in October (Figure 3.7). 'Young-at-foot' decreased from 18% of the kangaroo MNKA in February, to 3% of the MNKA in August (Figure 3.7).

Table 3.1. The MNKA for kangaroos at Heritage Park for each sampled month from December 2015 to October 2016. The difference between the maximum and minimum counted indicates the variability between counts.

Month	MNKA (max. counted)	min. counted	max/min. difference
December	274	-	-
February	274	243	31
April	290	188	102
June	260	199	61
August	252	190	62
October	312	266	46

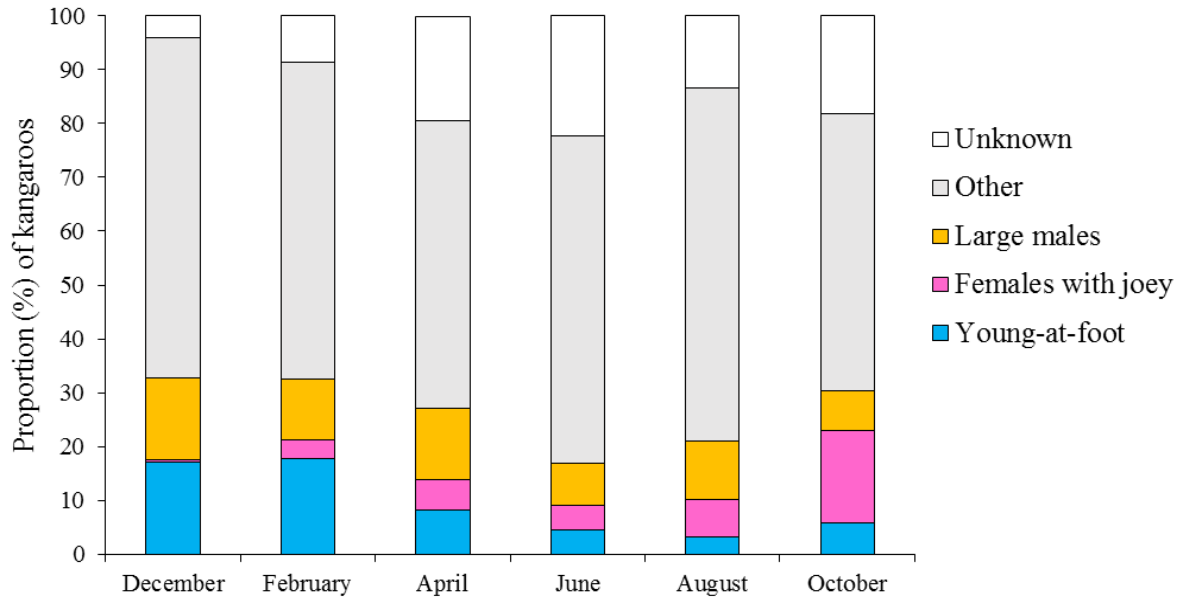

Figure 3.7. The proportion of kangaroos by category for the MNKA count for each sampled month at Heritage Park from December 2015 to October 2016.

Avocado Heights

Kangaroo MNKA varied greatly throughout the year, with peaks in February (61 individuals) and June (62 individuals), and a decline in August (33 individuals) (Table 3.2). There was a large difference (47 individuals) between the minimum and maximum number of individuals counted for February, indicating inconsistencies in the counts (Table 3.2). 'Large males' peaked at 11% of the kangaroo MNKA in June (Figure 3.8). The proportion of 'females with joeys' peaked in October at 12% of kangaroo MNKA (Figure 3.8), while 'Young-at-foot' made up between 7-12% of the kangaroo MNKA across all months (Figure 3.8).

Table 3.2. The MNKA for kangaroos at Avocado Heights for each sampled month from December 2015 to October 2016. The difference between the maximum and minimum counted indicates the variability between counts.

Month	MNKA (max. counted)	min. counted	max/min. difference
December	31	-	-
February	61	14	47
April	50	28	22
June	62	45	17
August	33	31	2
October	49	35	14

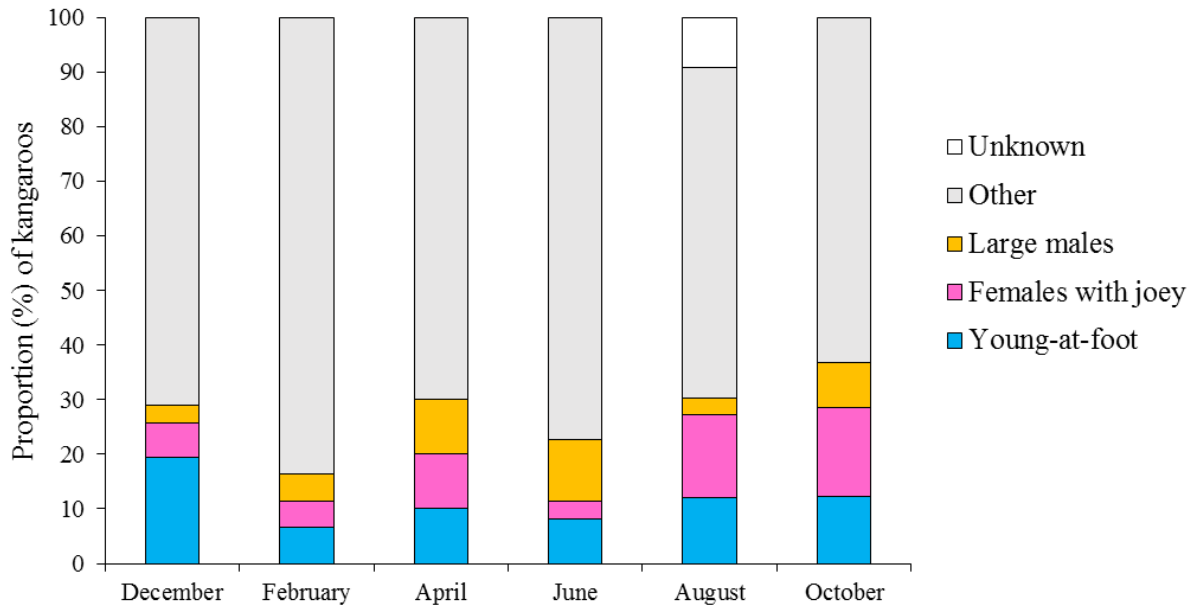

Figure 3.8. The proportion of kangaroos for each category for the MNKA count for each sampled month at Avocado Heights from December 2015 to October 2016.

Emerald Beach Headlands

Kangaroo MNKA declined from over 100 individuals in February and April to less than 60 individuals present in August (Table 3.3). February counts however had a large difference of 56 individuals, compared to the four other monthly counts (Table 3.3). The proportion of 'large males' consistently made up between 9% and 13% of the kangaroo MNKA over the year (Figure 3.9). There was an obvious increase in the proportion of 'females with joeys' during the year; which peaked in October, making up 26% of the kangaroo MNKA (Figure 3.9).

Table 3.3. The MNKA for kangaroos at the Emerald Beach headlands for each sampled month from December 2015 to October 2016. The difference between the maximum and minimum counted indicates the variability between counts. *only the LAMN headland section was surveyed on this occasion.

Month	MNKA (max. counted)	min. counted	max/min. difference
December	15*	-	-
February	106	50	56
April	112	84	28
June	79	48	31
August	52	48	4
October	85	60	25

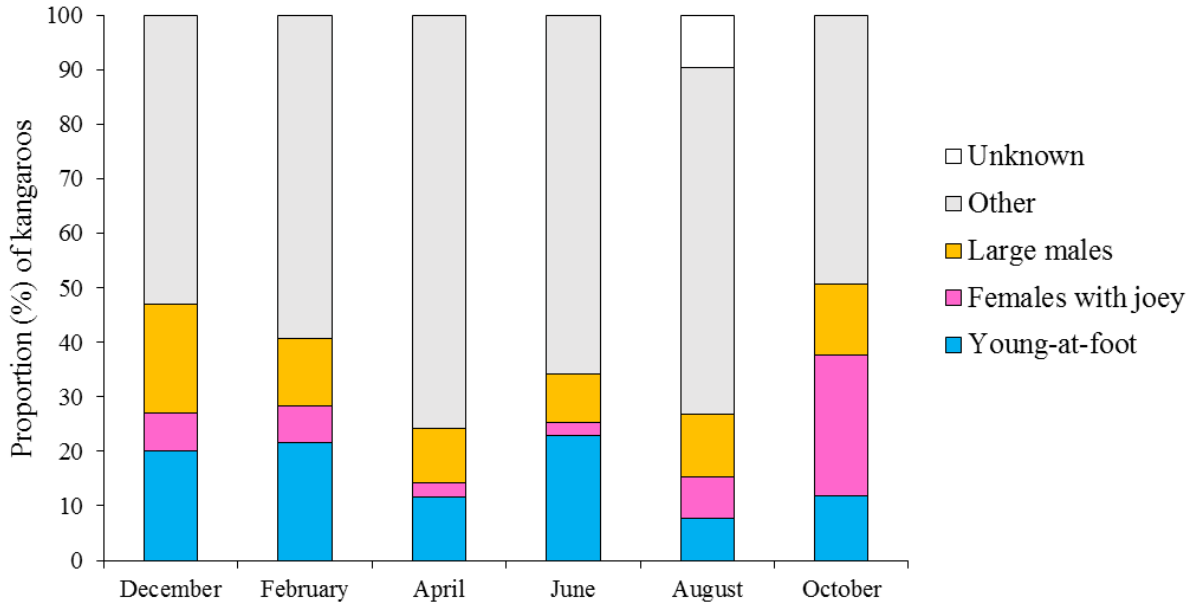

Figure 3.9. The proportion of kangaroos for each category for the MNKA count for each sampled month at the Emerald Beach headlands from December 2015 to October 2016. Note: December consisted of singular count for the LAMN headland only.

Safety Beach Golf Course

Kangaroo MNKA remained between 99 and 109 individuals throughout the year, with the exception of June (74 individuals), which declined by 25 individuals from April (Table 3.4). Each sampled month had only minor differences between minimum and maximum counts, indicating precision in the kangaroo MNKA counts (Table 3.4). The proportion of 'Large males' on the golf course remained between 7% and 11% of the kangaroo MNKA for each sampled month (Figure 3.10). The golf course also had a large increase in the proportion of 'females with joeys', which made up < 1% of the kangaroo MNKA in February, to 12% of the MNKA in August and 24% of the MNKA in October (Figure 3.10).

Table 3.4. The MNKA for kangaroos at the Safety Beach golf course for each sampled month from December 2015 to October 2016. The difference between the maximum and minimum counted indicates variability.

Month	MNKA (max. counted)	min. counted	max/min. difference
December	107	-	-
February	102	100	2
April	99	87	12
June	74	68	6
August	107	95	12
October	109	100	9

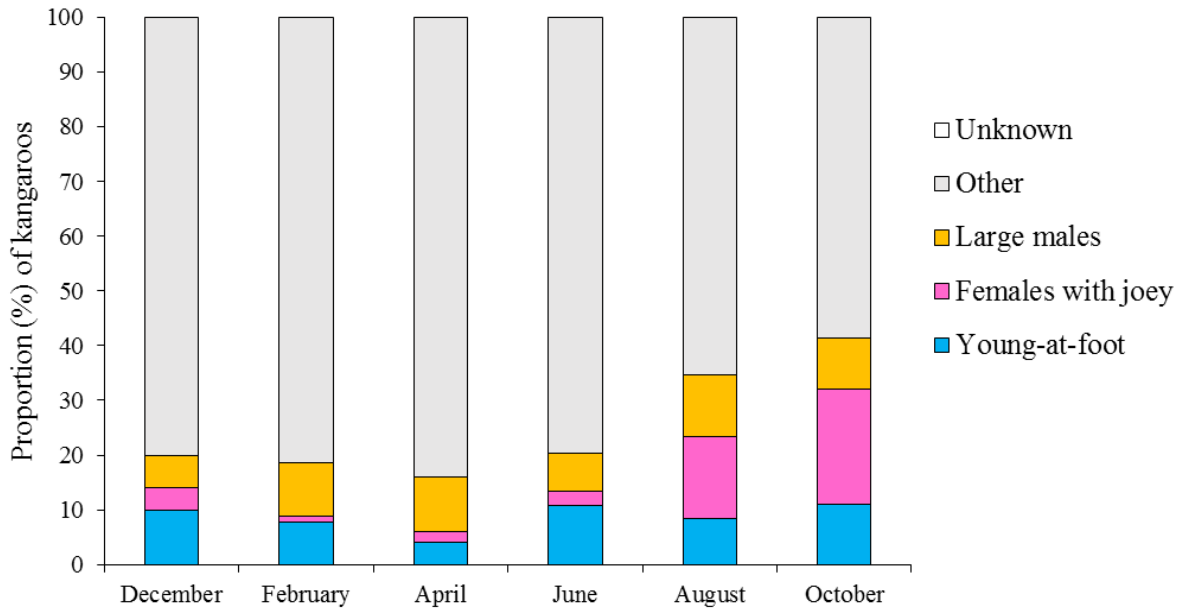

Figure 3.10. The proportion of kangaroos for each category for the MNKA count for each sampled month on the Safety Beach golf course from December 2015 to October 2016.

3.4 Discussion

It is clear that Heritage Park has the highest number of kangaroos of all hotspot sites, with the minimum number known to be alive (MNKA) exceeding 300 kangaroos. This was consistent with counts conducted by the NPWS at Heritage Park from early-mid 2015, which recorded 306 to 314 kangaroos (WIRES, NPWS, CHCC, 2016). Numbers had been increasing yearly to this point. However, my counts for 2016 show no increase in abundance, with most months recording between 250 and 290 kangaroos at Heritage Park. There is no obvious cause for this although it is likely that differences between NPWS counts and my counts may be a result of inconsistencies in sampling methods combined with observer difference.

Across all sites, kangaroo numbers were highest in the warmer months (February, April and October), with a slight decline in winter (June and August). This may indicate seasonal changes in kangaroo habitat occupancy with kangaroos potentially dispersing during these months (Coulson et al., 2014). The consistent occurrence of 'females with joeys' and 'young-at-foot' imply that kangaroos here breed throughout the year. However, increases in the number of 'females with joeys' in August and October suggest that breeding peaks in summer, resulting in pouched joeys and young-at-foot appearing in the following spring. The proportion of 'large males' remained the same at all sites throughout the year, suggesting possible high site fidelity by large males. These findings are a contradiction to other studies which report on sexual segregation of males during the non-breeding seasons (autumn and winter) for both peri-urban and rural kangaroo populations (Coulson et al., 2006; Coulson et al., 2014). The reason why large males in my study potentially exhibited annual site fidelity is unknown. However, Chapter 5 explores the movement patterns of male kangaroos in more detail.

Kangaroo densities at Heritage Park, the Emerald Beach headlands and the Safety Beach golf course, can all be considered high when compared to other records of kangaroo densities. For example, Emerald Beach reached a maximum density of 4.87 ha^{-1} (112 individuals) in April, which is similar to the maximum densities of 5 ha^{-1} reported in the ACT Kangaroo Management Plan (2010) for kangaroo populations in reserves. High densities such as this can have severe impacts on the plant species composition in grassy ecosystems (Howland et al., 2014). There is a current ongoing study on the impacts of kangaroo grazing on the Emerald Beach headlands (Helen Morgan, UNE researcher, pers. comm) which will gather more detailed information on changes in plant species composition and abundance.

The population of kangaroos on the headlands appeared to decline in August to about 50% of what it was in April. A possible explanation for this decline is the activity of dogs during June and August. A June morning count was interrupted by a non-leashed domestic dog which proceeded to chase away all kangaroos on LAMN headland, resulting in an incomplete count. It is unknown how often this occurs and if this has impacted upon the results of subsequent counts. Furthermore, during the August counts, there were obvious signs of dog activity (either wild dog or domestic dog) which included fresh tracks and a mauled joey on LAMN headland. Ballard (2006) reported on community concerns for kangaroo-dog conflict on the Coffs Coast, with residents reporting injuries and deaths of both dogs and kangaroos. This is a clear management issue for the area which requires investigation by local authorities as dogs are prohibited from the headlands by law.

Counts at the Safety Beach golf course were consistent throughout the year, with only slight variations between the highest and lowest counts for each month. This suggests that counts here may be a close representation of the true population, especially considering the ease of which the entirety of the golf course can be surveyed. However, because the southern boundaries of the golf course connect to the residential area of Safety Beach, the golf course kangaroo population cannot be considered a closed population. The density of kangaroos on the golf course ranged from 1.5 ha^{-1} in June to 2.3 ha^{-1} in October. These densities were smaller than densities reported by Coulson et al. (2014) on the Anglesea golf course in Victoria, which peaked at 4.9 ha^{-1}. Local human perceptions of kangaroo abundance indicate a decline in kangaroo numbers since the construction of the new Pacific Motorway (completed in 2014), which has allowed for increased dispersal across the old Pacific Highway into the western part of the Woolgoolga township. However, this decline cannot be confirmed as no surveys were conducted on the golf course population prior to the new Pacific Motorway being constructed.

The density of kangaroos at Heritage Park, derived from distance sampling, reached a maximum of almost 2.0 ha^{-1} in October. As there is no literature on kangaroo densities within residential areas, I cannot ascertain the veracity of these estimates. However, kangaroo density is almost certainly influenced by the availability of space in the urban area, especially if compared to a density of similar value in a more natural area. When comparing densities from distance sampling to direct counts, distance sampling was consistently higher as expected. There are, however, apparent advantages and disadvantages to distance sampling. Firstly, distance sampling proves to be a simple, alternative method to direct observation counts in estimating kangaroo density. Streets can be utilized to systematically place transects as

kangaroo distribution appears to be unaffected by the street layout, with large numbers of kangaroos being recording within metres of the road. Secondly, as properties and forest may limit kangaroo detectability (i.e. kangaroos may be missed), distance sampling can reliably calculate a density estimate based on the clusters that were detected and their distance from the transect line. However, as properties can often be close to transects, detection of near animals may actually be reduced. This could result in a 'bell' shaped detection function to severely impact the density estimate. Fortunately, this did not seem to be an issue at Heritage Park, but may be a problem in areas where properties are smaller and closer together. Although this study revealed that distance sampling represents a potentially viable method of surveying large kangaroo populations in peri-urban areas, confirmation of its effectiveness would need to be tested against other contemporaneous sampling methods.

Chapter 4: Human perceptions of peri-urban kangaroos in the Coffs Harbour Northern Beaches region

4.1 Introduction

Research on human dimensions has been recognized as equally important as ecological research in wildlife management (Enck et al., 2006). In urban areas, where wildlife management is perhaps at its most contentious, understanding and engaging the community should be the forefront of management based decision making (Lunney and Burgin, 2004a). By incorporating community and stakeholder input, managers can work towards an outcome that is most appropriate for the management of urban wildlife (Decker and Chase, 1997). Residents can provide managers with important local knowledge on wildlife, as well as their perceptions and attitudes towards them (FitzGibbon and Jones, 2006). Researchers can access this source of knowledge through question based survey techniques.

In Australia, questionnaire surveys regarding urban wildlife management have been used for a number of species that come into conflict with people, such as urban possums (Hill et al., 2007), and more pertinently, peri-urban kangaroos (Ballard, 2006). The comprehensive research undertaken by Ballard (2006) assessed the attitudes and perceptions of coastal communities towards resident kangaroo populations, and the value of community engagement in wildlife management. Three communities within the Coffs Harbour Northern Beaches region (Heritage Park, Avocado Heights and Safety Beach) were included in his research. However, as the research by Ballard (2006) was undertaken 10 years ago, and human-kangaroo conflict is perceived to have increased during the last decade, an updated understanding of the issue was required.

This study reports on a community-based survey which was used to gain an understanding of human perceptions and values towards kangaroos and the management of kangaroos in the Coffs Harbour Northern Beaches region. The results obtained in this study will subsequently be utilized by the local NPWS and Coffs Harbour City Council to appropriately engage local communities and formulate strategies for managing human-kangaroo interactions.

4.2 Methods

4.2.1 Study sites

While the entire Coffs Harbour Local Government Area was the target of this study, I specifically focused my efforts on the five 'kangaroo hotspot' communities outlined in Chapter 2. These were Heritage Park, Avocado Heights, Emerald Beach, Safety Beach, and specific areas within Woolgoolga.

4.2.2 Development of the survey

The survey was developed following a Coffs Harbour Kangaroo Management Committee meeting in which key issues of concern were identified. I created questions using Ballard (2006) as a benchmark, and input from various NPWS representatives. The online survey instrument 'Survey Monkey' (www.surveymonkey.com), was used to create the survey and was initially trialed among the Kangaroo Management Committee members. Subsequent feedback from that committee was used to improve the survey prior to implementation. The survey included 54 multiple choice or short answer questions relating to respondents' demographics, their perceptions towards kangaroo abundance and management, and their interactions with kangaroos (see Appendix A for entire questionnaire).

4.2.3 Survey advertisement

The survey was advertised through the Coffs Harbour Advocate, the Woolgoolga Advertiser, and the local ABC radio. An online link to the survey was provided on the Coffs Harbour City Council website. To further encourage responses, the CHCC facilitated mail-outs to the five communities of interest, totaling 2386 households. This mail-out included an introduction to the survey and provided a web-link and QR (quick response) scan code to the survey. The survey was live for 8 weeks (December 2015 – February 2016), with an additional reminder in the media two weeks before the closing date.

4.2.4 Data analysis

Survey Monkey returns response specific figures and statistics for each question to enable independent analysis. Because of a large number of questions, I have only reported on key questions which will aid further community engagement initiatives in the Coffs Harbour Northern Beaches region. Some analysed questions looked at the overall combined responses from the region, while other questions were analysed with a focused on differentiating the

individual responses from the five targeted communities. The program Statistix (Version 10.0), was used to perform chi-square tests to compare the observed frequencies of responses between communities and/or questions. The level of significance for tests was 0.05. Questions were sometimes skipped by respondents; non-response counts were not included in analyses.

4.3 Results

4.3.1 Summary of responses

Woolgoolga had the highest number of responses (n = 94). However, it returned the lowest response rate at 9% (Table 4.1). The total response rate for communities which received mail-outs was 13%, with Heritage Park returning the highest response rate at 28% (Table 4.1). There were 31 responses (10% of total responses) from various communities that were not subjected to mail-outs. Of these communities, Mullaway (n = 7), Moonee Beach (n = 5) and Arrawarra (n = 5) had the most responses.

The median age group of respondents was 55 to 64 for all communities except Avocado Heights, which was 45 to 54 (Table 4.2). There was a higher proportion of female respondents than male respondents for all sites, particularly in Woolgoolga and Safety Beach (Table 4.2).

Table 4.1. Summary of the number of properties subject to mail-outs as well as the number of responses and corresponding response rate. 'Other' was an open-ended response.

Community	No. of properties subject to mail-out	No. of survey responses	Response rate (%)
Heritage Park	178	50	28.1
Avocado Heights	160	20	12.5
Emerald Beach	603	64	10.6
Woolgoolga	1019	94	9.2
Safety Beach	429	80	18.6
Coffs Harbour	0	5	n.a.
'Other'	0	31	n.a.
Total	2389	344*	12.9

* 308 of these responses were from communities targeted by the mail-out. 36 of these responses came from Coffs Harbour, or from respondents who specified their location in the open-ended 'other' category.

Table 4.2. Summary of median age group and proportion of male to female respondents from the five target communities.

Community	Median age group	Proportion (%) of males | females
Heritage Park	55 to 64	42 | 58
Avocado Heights	45 to 54	45 | 55
Emerald Beach	55 to 64	31 | 61
Woolgoolga	55 to 64	31 | 61
Safety Beach	55 to 64	48 | 52

4.3.2 Responses to key questions relating to kangaroo abundance

Q6: "How many years have you lived at your current address?" and Q19: "Since living at your current address, do you believe kangaroo numbers have increased, decrease or stayed the same?"

These two questions were combined to provide a perception on how kangaroo numbers have changed over time, across the Coffs Harbour Northern Beaches. The majority of respondents (53%) indicated that they had lived at their current address for more than 10 years. Chi-squared analysis revealed a significant difference between respondents years of residency and the perception of changes in kangaroo numbers ($X^2 = 102.25$, $d.f. = 9$, $P < 0.001$). There was a greater perception of an increase in kangaroo numbers in longer-term residents, especially residents who have lived at the current address for more than 10 years (Figure 4.1). There was high uncertainty (45%) among newer residents (less than a year at current address) and over 50% of respondents with 1 – 5 years at their current address believed that kangaroo numbers have stayed the same since moving there (Figure 4.1).

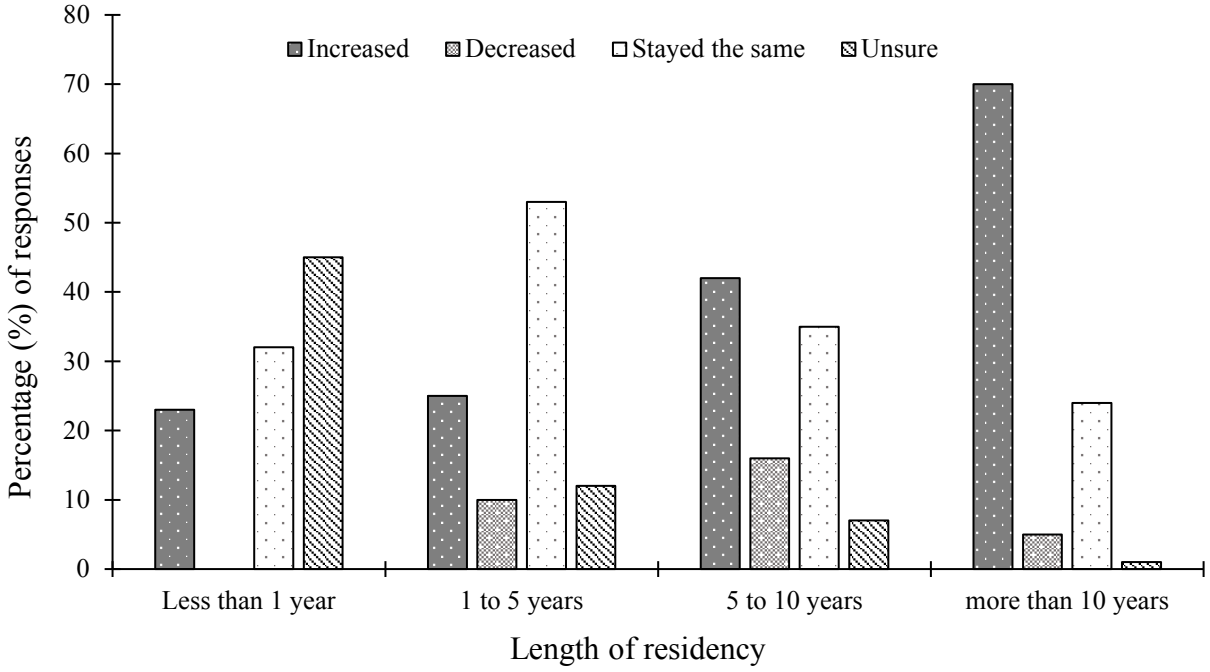

Figure 4.1. Proportion of responses in answer to Q19 "Since living at your current address, do you believe kangaroo numbers have increased/decrease/stayed the same?" categorized by years of residency.

Q18: "In your local area, do you believe kangaroo numbers are: high, about right, or low?"

There were no significant differences between communities in response to this question (X^2 = 14.86, *d.f.* = 8, *P* = 0.062). However, over half of the respondents from Emerald Beach, Woolgoolga and Safety Beach were of the opinion that kangaroo numbers are 'about right', while half of the respondents from Heritage Park and 58% from Avocado Heights considered kangaroo numbers to be 'high' (Table 4.3). In contrast, only 26% of respondents from Safety Beach believed that kangaroo numbers were 'high' (Table 4.3). There was a low proportion of residents from each community who thought kangaroo numbers were 'low', with Woolgoolga recording the greatest proportion at 8% (Table 4.3).

Table 4.3. Proportion of responses from each community, in answer to Q18 "In your local area, do you believe kangaroo numbers are: high, about right, or low?"

Community	High	About right	Low
Heritage Park	50%	48%	2%
Avocado Heights	58%	37%	5%
Emerald Beach	35%	60%	5%
Woolgoolga	40%	52%	8%
Safety Beach	26%	70%	4%

Q36: "Which of the following methods for controlling kangaroo numbers in your local area do you NOT agree with?"

There were no significant differences between communities in response to this question (X^2 = 5.71, *d.f.* = 12, *P* = 0.930). The majority of respondents (63%) did not agree with culling as a population control method, 31% of respondents did not agree with relocation, and over 40% did not agree with sterilization or fencing as population control methods (Figure 4.2).

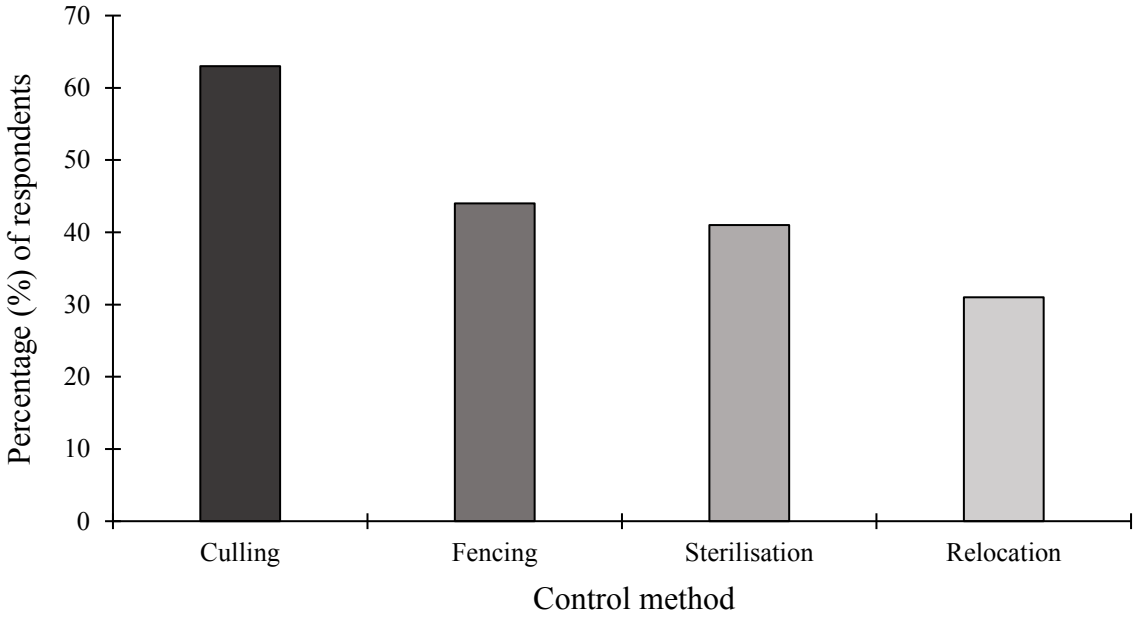

Figure 4.2. Proportion of respondents, in answer to Q36 "Which of the following methods for controlling kangaroo numbers in your local area do you NOT agree with?"

4.3.3 Responses to key questions relating to interactions with kangaroos

Q10: "Do you feel that kangaroos in your local area have a positive or negative impact on: a) your quality of life, b) the local environment, c) your appreciation for native wildlife?"

There was an overall perception that kangaroos have a positive impact on respondents' quality of life (Figure 4.3a). Emerald Beach had the highest percentage of 'positive' responses at 90%, while Woolgoolga had the highest percentage of 'negative' responses at 21% (Figure 4.3a). Similarly, with respect to 'impact on the local environment', Emerald Beach had the highest percentage of 'positive' responses (95%) and Woolgoolga had the highest percentage of 'negative' responses at 19% (Figure 4.3b). There was an overwhelming perception that kangaroos had a positive impact on a respondent's appreciation for native wildlife, with Woolgoolga and Avocado Heights scoring above 80% of respondents, and Heritage Park, Emerald Beach and Safety Beach above 90% of respondents (Figure 4.3c).

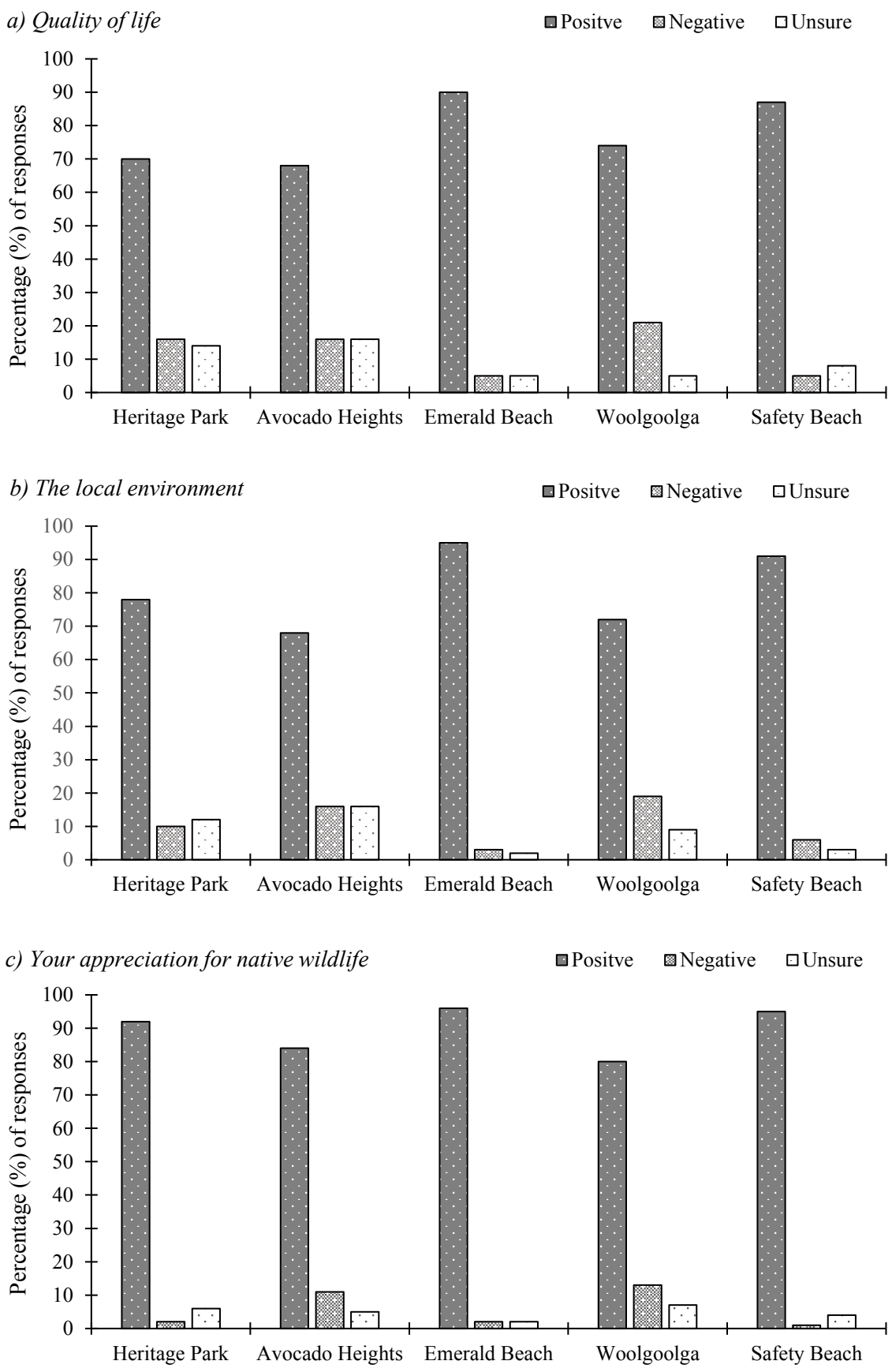

Figure 4.3 (a.b.c). Proportion of responses from each community, in answer to Q10: "Do you feel that kangaroos in your local area have a positive or negative impact on: a) your quality of life; b) the local environment; and c) your appreciation for native wildlife?"

Q40: "Are you concerned about potential conflict between yourself and kangaroos in your local area?"

There were significant differences detected between communities in response to this question ($X^2 = 24.22$, *d.f.* = 8, $P < 0.01$). However, further analysis revealed no significant difference between Heritage Park and Woolgoolga ($X^2 = 0.53$, *d.f.* = 2, $P = 0.769$), and no significant difference between Emerald Beach and Safety Beach ($X^2 = 1.16$, *d.f.* = 2, $P = 0.559$). Avocado Heights was the only community where more respondents were concerned (47%) than not concerned (42%), about potential conflict with kangaroos (Figure 4.4). There were moderate concerns for human-kangaroo conflict among respondents from Heritage Park (36%) and Woolgoolga (35%) (Figure 4.4). Both Emerald Beach (20%) and Safety Beach (14%) had a low number of respondents concerned about potential conflict with kangaroos (Figure 4.4).

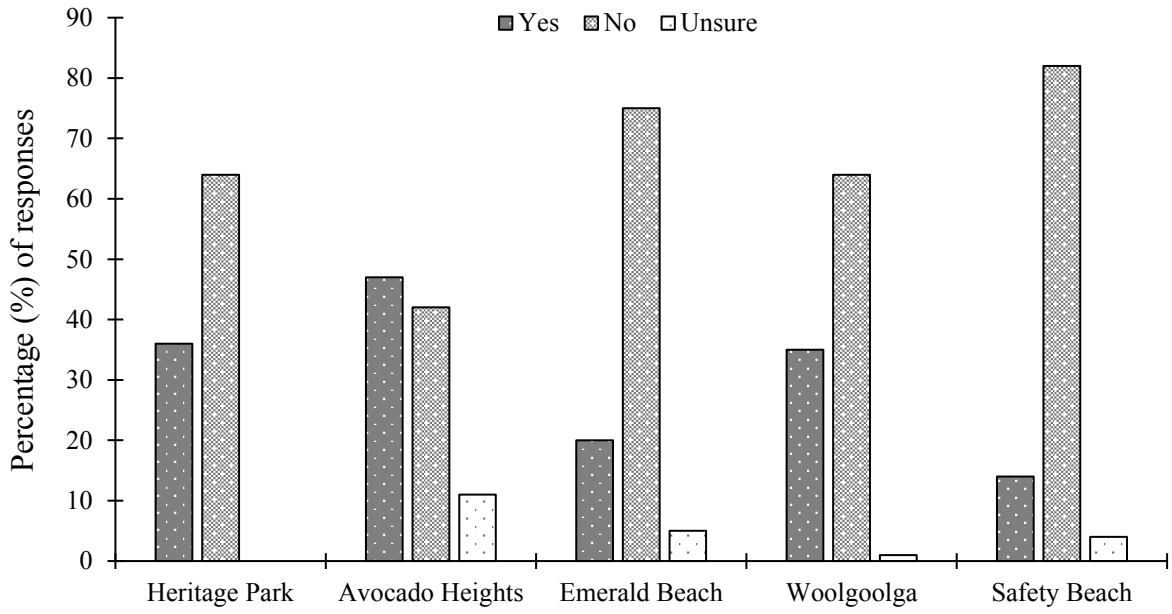

Figure 4.4. Proportion of responses from each community, in answer to Q40 "Are you concerned about potential conflict between yourself and kangaroos in your local area?"

Q45: "If attacked by a kangaroo, what would you most likely do?"

Respondents were most likely to 'curl into a ball' (44%) if attacked by a kangaroo (Figure 4.5), with a significant difference between how males and females responded to this question ($X^2 = 42.81$, *d.f.* = 5, $P < 0.001$). Females were more likely to curl into a ball and call for help, whereas males were more likely to run away or fight back (Figure 4.5).

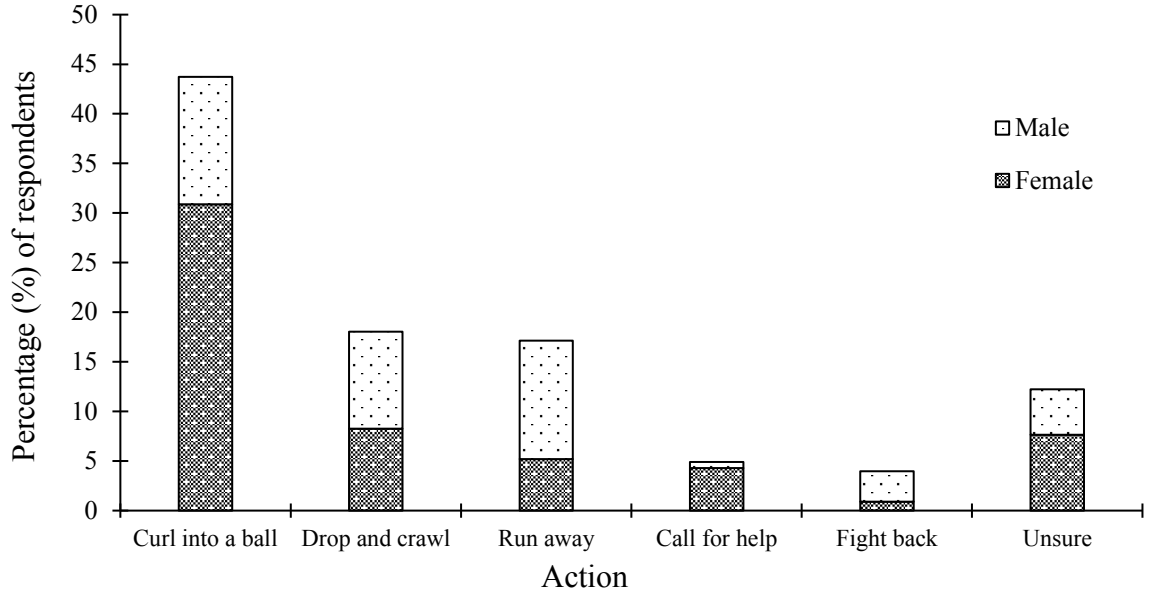

Figure 4.5. Proportion of responses in regards to their gender, in answer to Q45 "If attacked by a kangaroo, what would you most likely do?"

Q41: "Which interactions are you most concerned about regarding humans – kangaroo interactions and dog – kangaroo interactions?"

The level of concern for each interaction was determined by asking the respondent to order the interactions from one (lowest concern) to four (highest concern). A value of one to four was then assigned to each level of concern where: 1 = lowest concern and 4 = highest concern. Overall, 'dogs attacking kangaroos' was the interaction of most concern to respondents, while 'kangaroos attacking dogs' was of least concern (Figure 4.6).

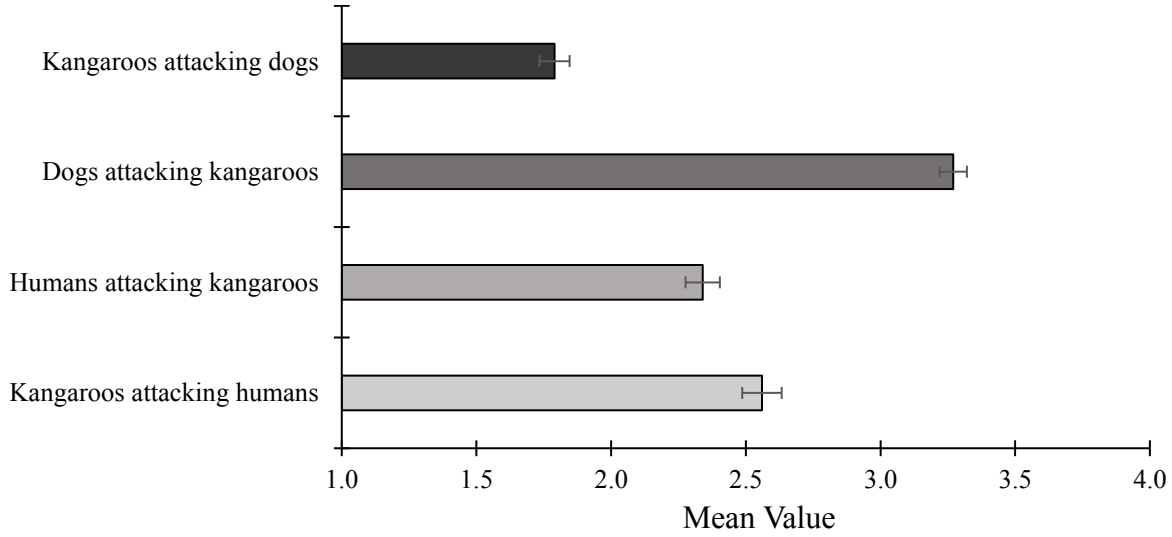

Figure 4.6. The mean level (with standard error bars) of respondents concern, in answer to Q41 "Which interactions are you most concerned about regarding humans – kangaroo interactions and dog – kangaroo interactions?"

Q21: "Are you concerned about the chance of collision between vehicles and kangaroos in your local area?" and "Within the last year, have you been involved in a vehicle collision (Q22) or near-collision (Q23) with kangaroos in your local area?"

Concerns for vehicle collision with kangaroos was highest among respondents from Heritage Park (76%) and Avocado Heights (90%), and lowest among respondents from Emerald Beach (41%) (Table 4.5). This corresponds with Heritage Park and Avocado Heights having the highest proportion of respondents saying they have been involved in a collision (Heritage Park, 24%; Avocado Heights, 26%) or near-collision (Heritage Park, 80%; Avocado Heights, 89%) with kangaroos, and Emerald Beach having the lowest (collision, 3%; near-collision, 47%) (Table 4.5). The proportion of respondents concerned about collision was significantly higher in respondents who had been involved in a collision in the last year (Fishers exact test, two-tailed p-value < 0.001). This was also the case for respondents who had been involved in a near-collision within the last year (Fishers exact test, two-tailed p-value < 0.001).

Table 4.5. Proportion of responses from each community, in answer to Q21 (concerned about vehicle collision with kangaroos), Q22 (involvement in collisions) and Q23 (involvement in near-collisions).

Community	Concerned about collision	Collision	Near-collision
Heritage Park	76%	24%	80%
Avocado Heights	90%	26%	89%
Emerald Beach	41%	3%	47%
Woolgoolga	59%	9%	54%
Safety Beach	54%	6%	64%
Overall	59%	10%	60%

Q26: "Which of the following would you suggest to reduce vehicle incidents with kangaroos?"

There were no significant differences between communities in response to this question (X^2 = 27.51, *d.f.* = 24, *P* = 0.281). Wildlife signage was the most popular choice as a vehicle collision mitigation method at 66% (Figure 4.7). There was also an 'other' category included in this question, in which 30% of respondents added their own comment/suggestion. Although many of these responses were not entirely relevant to the question, there were some noteworthy suggestions which included: Speed limit reduction for certain time periods only; increased awareness of the issue in local media; and better education regarding wildlife on roads and in schools, including driving schools.

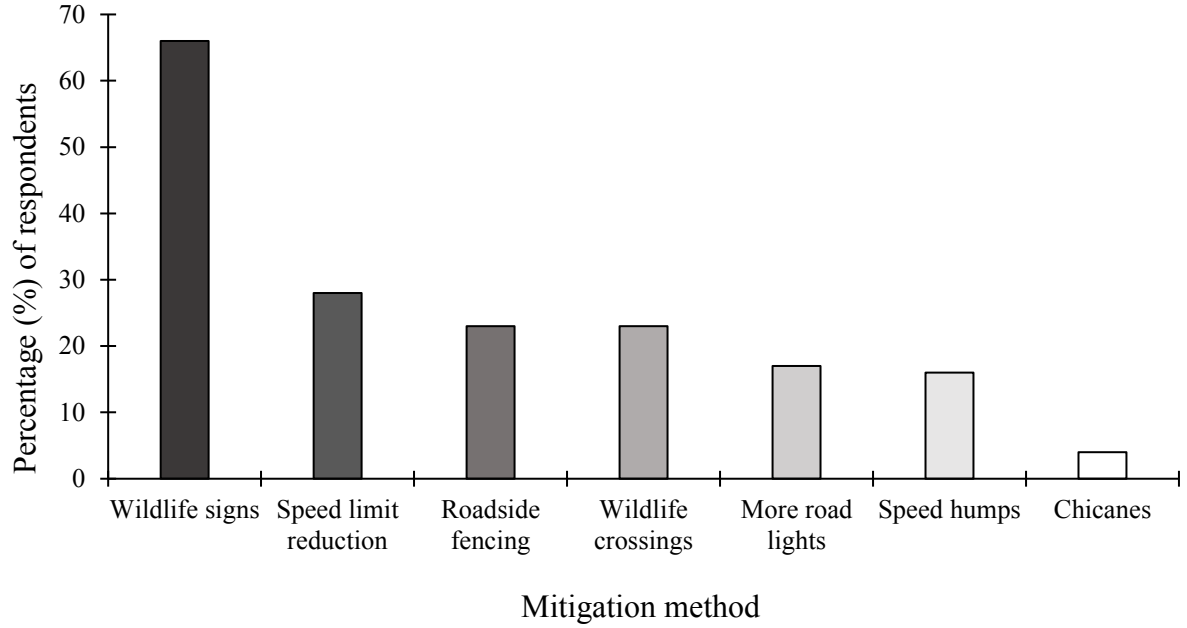

Figure 4.7. Proportion of respondents in answer to Q26 "Which of the following would you suggest to reduce motor vehicle incidents with kangaroos?"

4.3.4 Responses to questions relating to conservation education

Q31: "Do you think kangaroos are protected: Everywhere in NSW?"

There were no significant differences between communities in respondents' knowledge on whether kangaroos are protected or not in NSW ($X^2 = 5.08$, *d.f.* = 4, $P = 0.280$). Woolgoolga had the highest proportion of respondents (59%) who believe kangaroos are protected, while Avocado Heights had the lowest (37%) (Figure 4.8).

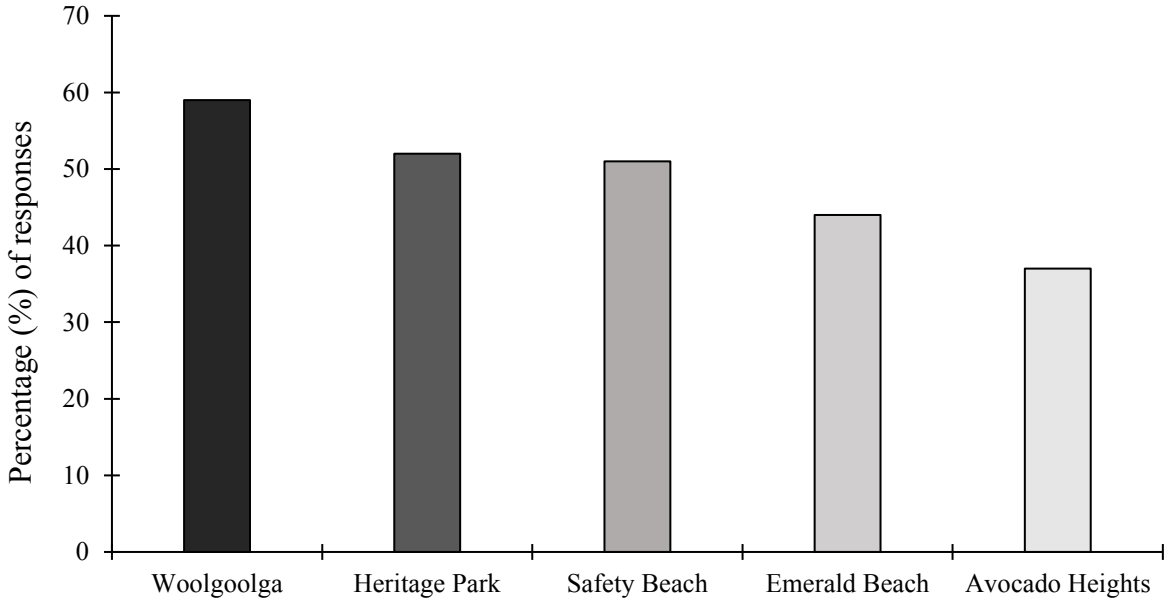

Figure 4.8. Proportion of respondents from each community who believe kangaroos are protected in NSW.

Q46: "If reporting an aggressive kangaroo, who would you most likely contact?"

There were significant differences between communities in response to this question (X^2 = 28.45, *d.f.* = 16, $P < 0.05$). When Heritage Park was removed from the analysis, responses from the other communities were not significantly different (X^2 = 10.38, *d.f.* = 12, $P = 0.582$). The NPWS was the common choice for reporting aggressive kangaroos among respondents from Emerald Beach (67%) and Woolgoolga (54%) (Table 4.6). However, a higher proportion of respondents from Heritage Park (66%) preferred reporting aggressive kangaroos to WIRES, while a higher proportion of respondents from Avocado Heights (53%) preferred the CHCC as the first point of contact (Table 4.6). The RSPCA (5% total) and police (9% total) were the least common choices of contact among respondents (Table 4.6).

Table 4.6. Proportion of respondents from each community, in answer to Q46 "If reporting an aggressive kangaroo, who would you most likely contact?"

	Percentage of respondents would report an aggressive kangaroo to:				
Community	NPWS	WIRES	CHCC	RSPCA	The Police
Heritage Park	43%	66%	34%	4%	2%
Avocado Heights	47%	32%	53%	5%	11%
Emerald Beach	67%	20%	39%	5%	8%
Woolgoolga	54%	41%	42%	8%	11%
Safety Beach	49%	34%	48%	4%	14%
Total	55%	39%	40%	5%	9%

Q47: "Do you feel informed from the local National Parks and Wildlife Services and Coffs Harbour City Council about what to do and what not to do when around kangaroos?"

A score was determined for each community by assigning a value between 1 and 5 to each response where: 1 = highly uninformed; 2 = somewhat uninformed; 3 = neutral; 4 = somewhat informed; and 5 = highly informed. Overall mean scores indicated that respondents from each community generally felt uninformed from the local NPWS and CHCC on what to do and not to do when around kangaroos (Figure 4.9). However, respondents from Emerald Beach did feel the most informed from the local NPWS and CHCC out of all the communities, while Woolgoolga felt the least informed (Figure 4.9).

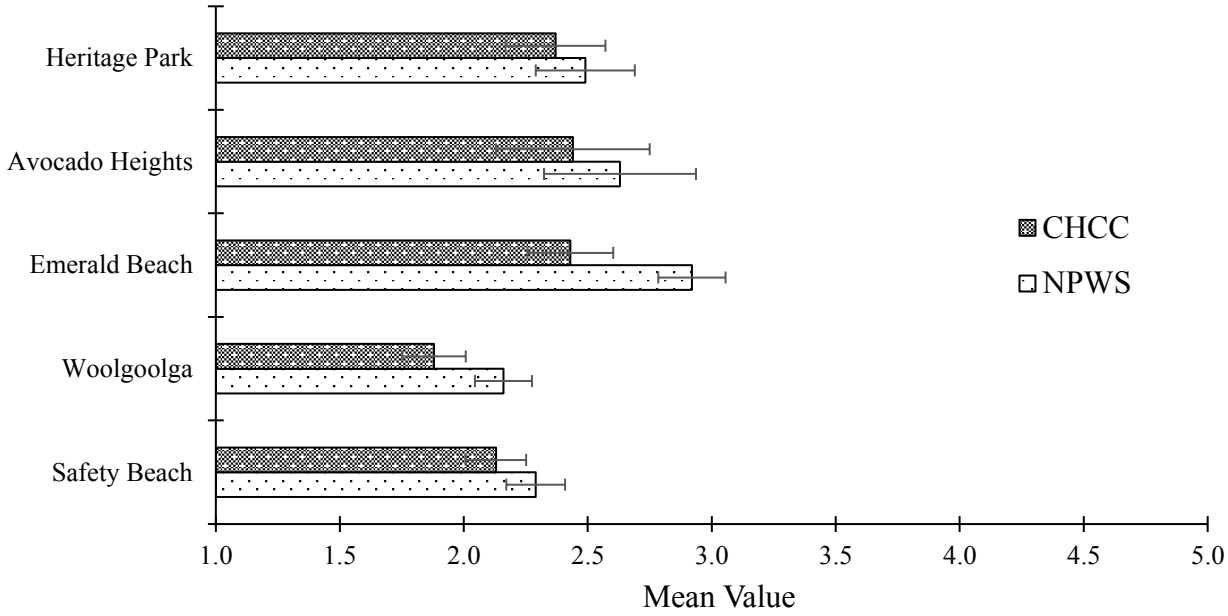

Figure 4.9. The mean level (with standard error bars) of how informed respondents felt, in answer to Q47 "Do you feel informed from the NPWS and CHCC about what to do and what not to do when around Kangaroos?"

Q48: "Are you aware of the NPWS 'Living with Kangaroos' educational program?"

Only 19% of respondents indicated that they were aware of the NPWS 'Living with Kangaroos' educational program, which was promoted in local schools (Figure 4.10a).

Q50: "Have you been exposed to any other educational materials relevant to kangaroo management issues?"

Only 18% of respondents indicated that they were exposed to other educational programs relating to kangaroo management issues (Figure 4.10b).

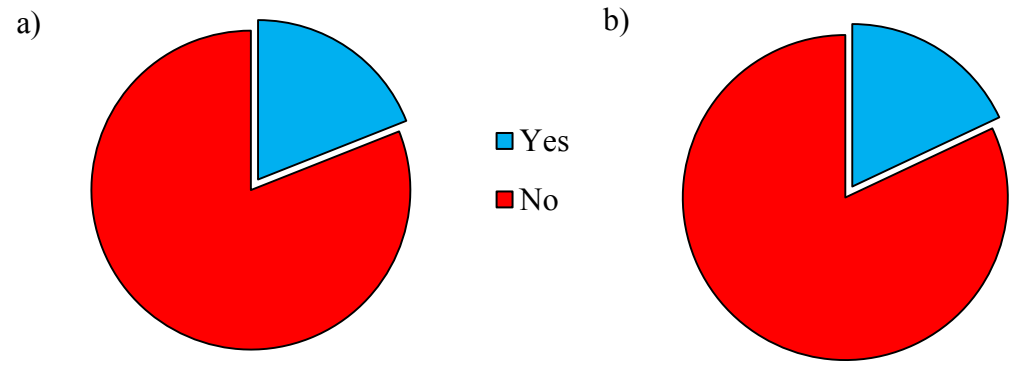

Figure 4.10. a) The proportion of respondents who were aware of the NPWS 'Living with Kangaroos' education program; and b) The proportion of respondents who have been exposed to other educational materials relevant to kangaroo management issues.

Q51: "Should people who move into an area with wildlife, such as kangaroos, be provided with appropriate information on how to live with these animals?"

95% of respondents believed that new home-owners should be provided with information of how to live with kangaroos (Figure 4.11a).

Q52: "If you were/are a new homeowner, would you accept a Kangaroo Covenant (agreement) as part of your purchase, and to apply Kangaroo mitigation measures?"

Responses were equally divided between respondents who would accept (38%), or not accept (38%) a kangaroo covenant if they were/are a new homeowner, with 24% of respondents uncertain (Figure 4.11b).

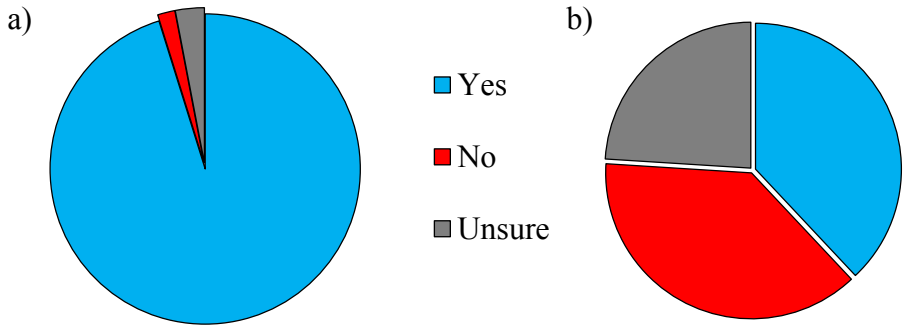

Figure 4.11. a) The proportion of respondents in response to Q51 "Should people who move into an area with wildlife, such as kangaroos, be provided with appropriate information on how to live with these animals?" and b) The proportion of respondents in response to Q52 "If you were/are a new homeowner, would you accept a Kangaroo Covenant (agreement) as part of your purchase, to apply Kangaroo mitigation measures?".

4.4 Discussion

The responses gained from this study provided important insights into the perceptions residents of the Coffs Harbour Northern Beaches have towards peri-urban kangaroos. Overall, there was a positive attitude towards kangaroos and their presence within local communities. Respondents, however, felt ill-informed from the NPWS and CHCC about human-kangaroo interactions, and had an overwhelmingly strong desire to provide new home-owners with appropriate information on how to live with kangaroos. There was also a clear lack of exposure to kangaroo related educational materials among respondents. This lack of engagement is a key management issue and one that is now being addressed as part of the Coffs Harbour Kangaroo Management Plan.

With respect to population control methods, over half of respondents were against culling, and interestingly, 40% were against sterilization. Based on direct engagement with several Heritage Park residents during my fieldwork, it became apparent that I misused the term 'sterilization' in my survey. Although I intended sterilization to mean a temporary disruption of fertility, it is likely that this was interpreted as permanent sterilization, and therefore potentially impacted the responses. When this was explained more accurately to residents that I subsequently had conversations with, they were more understanding and accepting of temporary fertility control as a population control method.

Responses were generally consistent between communities, although there appeared to be a slight difference between two groups of communities. Heritage Park, Avocado Heights and Woolgoolga often shared more similar responses with each other than with Emerald Beach and Safety Beach. Perceptions of kangaroos were less positive in Heritage Park, Avocado Heights and Woolgooga residents where kangaroo numbers were believed to be higher. There was also greater concern for conflict and vehicle collisions with kangaroos from these communities. In comparison, responses from Emerald Beach and Safety Beach were overwhelmingly positive, with a general perception that kangaroo numbers were 'about right' including much lower concern for conflict or vehicle collision. The likely reason for these differences is the dispersal of kangaroos throughout each site. Kangaroos in Heritage Park, Avocado Heights and certain parts of Woolgoolga, generally occur within the residential areas and are readily observed, so the likelihood of interactions are therefore potentially higher. In contrast, kangaroos are generally concentrated on both the headland reserves at Emerald Beach, and the golf course at Safety Beach, and are less commonly seen unless one went for a walk at the headlands or played golf during peak kangaroo activity, thereby resulting in less frequent interactions.

Past and present: Comparing findings to Ballard (2006).

The human dimensions research by Ballard (2006) on the Coffs Coast provided an innovative understanding of community perceptions towards peri-urban kangaroos. Three communities targeted in his study; Heritage Park, Avocado Heights and Safety Beach, can be compared to the findings from my study to assess similarities and differences in responses between similar questions asked, despite the temporal differences between studies.

Response rates reported by Ballard (2006) were much higher than my survey with Heritage Park twice as high, Avocado Heights four times higher and Safety Beach three times

higher. Ballard's methods of obtaining responses were much more intensive, with three rounds of surveying including face-to-face interviews. As my survey was conducted 10 years after Ballard's, an important question to compare is the length of residency for respondents and their perception of changes in numbers since they began living there. Interestingly, Ballard (2006) found that longer-term residents had a strong perception of decreased kangaroo numbers, whereas respondents in my survey showed a perception of increased numbers in longer term residents. This comparison further implies that in the last 10 or so years, residents of the Coffs Harbour Northern Beaches generally believed that kangaroo numbers are increasing. Concerns over potential conflict with kangaroos showed some interesting differences between our respective studies. Although Heritage Park had similar responses (Ballard 34% concern versus this study 36% concern), Avocado Heights residents had a much higher level of concern in my survey (Ballard 18% versus this study 49%), while Safety Beach residents exhibited a lower level of concern in my study (Ballard 26% versus this study 14%).

When comparing responses regarding concerns over collisions with kangaroos, there was a much higher proportion of concerned respondents in my survey for Heritage Park (Ballard's 64% versus this study 76%) and Avocado Heights (Ballard 73% versus this study 90%), and interestingly, a similar response rate for Safety Beach (Ballard's 55% versus this study 54%). This is very much in line with a higher proportion of Heritage Park and Avocado Heights respondents from my survey who were involved in kangaroo collisions compared to respondents in Ballard's survey.

There were some surprising differences between survey responses relating to what respondents would do if attacked by a kangaroo. The majority of respondents from my survey said that they would 'curl into a ball' if attacked, while responses from Ballard's survey were much more evenly dispersed across the various options with a higher proportion of uncertainty among respondents in how to respond to a kangaroo attack. This is particularly interesting from a wildlife manager's point of view as 'curl into a ball' is the promoted appropriate action to take if being attacked by a kangaroo. The higher proportion of respondents who selected this option implies that educational awareness in the last decade has potentially changed how people react towards an aggressive kangaroo.

Future questionnaire design and follow up recommendations

The contemporary approach of using an online survey was shown to be successful in this study. The benefits of my online survey lay in the ease of which it was promoted, and the flexibility

of respondents' participation. However, I did receive several complaints from respondents who said that their survey stopped working prior to completion. Fortunately, Survey Monkey usually saved participants' progress and they could recommence and complete their survey. Other respondents also commented on the length of the survey, believing it to be too long. Upon reflection, certain questions could have been omitted to allow me to consolidate my focus on the key questions presented in this chapter. Such an approach towards administrating less but more valuable questions could have potentially increased the overall response rate.

Specific aspects of the Coffs Harbour Northern Beaches Kangaroo Management plan aim to address the key findings from this chapter on human perception to kangaroos. As such, future adequately designed follow-up surveys to assess changes in perceptions once management practices have been put into place are essential.

Chapter 5: Movement patterns of adult male kangaroos in a peri-urban environment

5.1 Introduction

Understanding spatial and temporal patterns of mammals in an urban or peri-urban environment is a key component in the development of appropriate management strategies (Rhoads et al., 2010). Movement patterns have been well studied in peri-urban and exurban white-tailed deer in North America (Grund et al., 2002; Porter et al., 2004). These studies suggest that the urban environment has influenced deer home range sizes, activity and habitat usage by altering the structure and productivity of habitats and introducing movement barriers such as roads and properties (Grund et al., 2002; Porter et al., 2004; Storm et al., 2007). Movement patterns of kangaroos have been well studied in reserves and farmland (Viggers and Hearn, 2005). However, a recent study by Coulson et al. (2014) provides the only example of kangaroo movements in a peri-urban area. In their study, tagged kangaroo were monitored over six years using radio-tracking, camera trapping and citizen science. While this research provides a standard for seasonal patterns and general habitat usage of peri-urban kangaroos, information regarding how kangaroos use the peri-urban environment on a day to day basis remains limited.

Movements of animals can be studied using various techniques such as identification tagging, camera-trapping, Very High Frequency (VHF) radio-telemetry and more recently, Global Positioning System (GPS) telemetry (Matthews et al., 2013). GPS tracking can yield frequent and accurate location estimates. However, commercial devices are generally expensive (Goldingay, 2015). This price limitation can restrict wildlife research efforts which may be crucial to management. A recent study by Allan et al. (2013) assessed the use of cheap alternatives to commercial GPS devices, which are modified GPS data loggers initially built for recreational purposes. Their study showed the potential of using such devices in understanding the movement ecology of wildlife at a less limiting cost.

The previous two chapters provided context behind kangaroo numbers in the Coffs Harbour Northern Beaches region as well as the perceptions of local communities towards kangaroos. It became clear that one particular community, Heritage Park, was an important hotspot for kangaroo abundance and associated human-kangaroo interactions. Anecdotal

observations imply that numbers here were substantially higher before residential development began. This suggests that peri-urban development has provided conditions which have positively impacted kangaroo presence. However, as the populations of humans and kangaroos are likely to continue increasing in this area, an improved understanding of how kangaroos move within and interact with the peri-urban environment of Heritage Park is essential. Information gained on such kangaroo movement will be used in the management of kangaroos in Heritage Park, and will potentially be valuable for other scenarios where human and kangaroos co-exist in a peri-urban landscape.

The aim of this chapter was to provide a benchmark for detailed movement patterns and habitat use by adult male kangaroos in Heritage Park. This addressed several pertinent questions regarding how adult male kangaroos at Heritage Park utilized space and behaved in the peri-urban environment from a temporal perspective.

The specific questions were:

1. Do adult male kangaroos remain within the peri-urban landscape, or do they also occupy the surrounding forest?
2. What is their home range size?
3. How many residential properties are adult male kangaroos occupying and potentially interacting with?
4. What is their daily activity in respect to movement rates and spatial distribution relative to housing?

5.2 Methods

5.2.1 Study site

Kangaroos were monitored in the Heritage Park estate (see Chapter 1) from June (winter) to September (early spring) of 2016. As shown in Chapter 3, the site has a large population of kangaroos (1.7 ± 0.3 individuals per hectare in August) which live in close proximity to residential properties. Heritage Park provides ideal habitat for kangaroos, offering an abundance of grassy spaces, water resources and shelter. Kangaroos here can be observed occupying the front and backyards of residential properties, vacant blocks, and the floodway which runs through the middle of the site. The mix of fully fenced, partially fenced and unfenced properties has somewhat displaced kangaroos, which often appear in higher concentrations on unfenced or partially fenced properties and vacant areas.

5.2.2 Kangaroo capture and handling

Large adult male kangaroos were the focus of this study because they are of greatest concern with respect to negative interactions between kangaroos and local residents. Selection of individuals required suitable positioning, such as on a vacant block or open property with adequate space for safe capture and recovery. For individuals located on a property, permission to capture and handle the individual on that property was first verbally obtained from the resident. Before commencement of fieldwork, I compiled a list of addresses and contact numbers for properties which kangaroos were known to frequently occur on.

Individuals were captured using a Pneudart X-Caliber rifle loaded with a tranquilizing dart containing the sedative drug Zoletil. Dosage varied (200-300mg) depending on the estimated size of the individual. A licensed shooter operated the rifle, firing from either a vehicle or on foot when appropriate. Due to the tolerant behaviour of kangaroos towards human presence at Heritage Park, individuals were able to be darted from 10 to 15 metres away. The darted individual was observed from a safe distance until it appeared to be sedated and in a lateral recumbent position. Time until sedation varied between individuals, with some taking only a few minutes and others up to 15 minutes.

Two methods of GPS deployment were utilized: (1) Collars to gain detailed, longer-term data on kangaroo movements; and (2) cheaper, custom made, drop-off 'backpacks', to provide a short 'snap-shot' of movement patterns that allowed for an increased sample size of monitored individuals. Kangaroos fitted with collars required only small handling times due to the ease of attachment. The collars were placed around the individuals' neck with suitable tightness to reduce movement but not cause stress or irritation for the animal. The drop-off backpack devices required more handling to ensure attachment. To attach them, an electric shaver was used to create a device-sized patch to one side of the individuals' spine. This patch was located between the animals' shoulders to reduce the risk of the animal self-reaching the device and therefore potentially removing it (Figure 5.1). Surgical adhesive was applied to the back of the device, which was then placed the shaved patch and held there for about 30 seconds until the adhesive set. After attachment of the devices, I recorded length of the tail (cm), hind foot length (cm) and head length (cm) briefly examined the animal for signs of injury or disease, and assessed overall health. After handling was complete, the animal was observed from a distance until it had recovered. Recovery time varied between individuals, ranging from 2 to 4 hours.

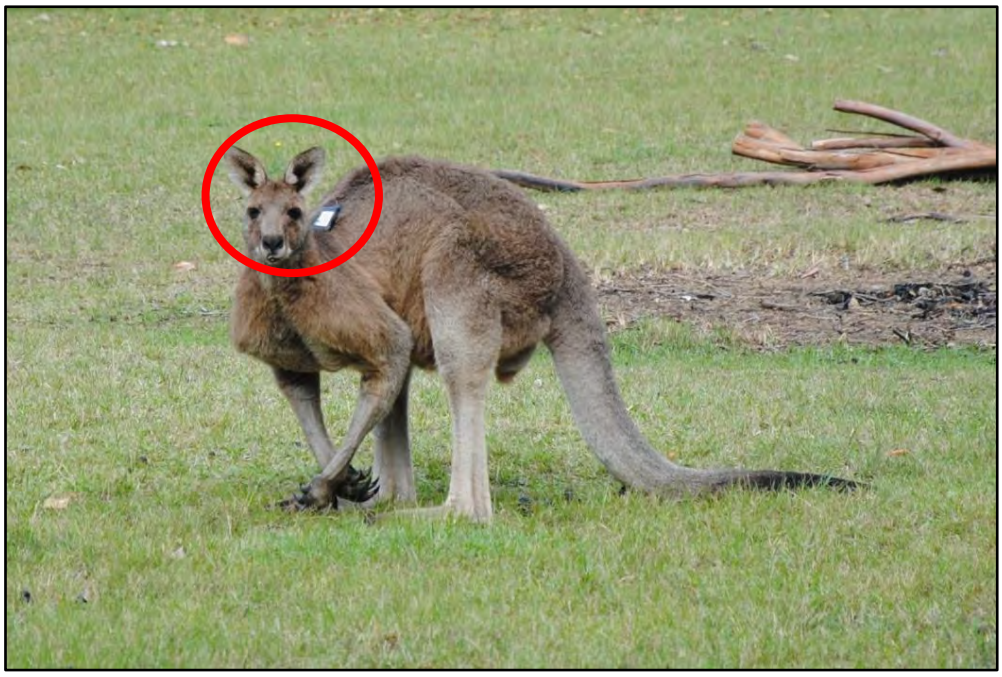

Figure 5.1. The position in which the drop-off backpack devices were attached to individuals. Placing the device just below the shoulders removes the stress placed on the adhesive when the kangaroos neck/shoulder bends, as seen in this individual.

5.2.3 GPS telemetry

I utilized four commercial GPS/VHF collars (Sirtack. Hawkes Bay, New Zealand), weighing approximately 120 grams each. These collars required the animal to be recaptured for retrieval. In addition, I also used six cheaper purpose-built GPS/VHF backpacks which were used as drop-offs. These devices were made by combining an i-gotU GT-120 GPS data logger (Mobile Action Technology, Taiwan) weighting approximately 20 grams each, with a VHF transmitter. Heat-shrink was used to seal the devices for further protection from water and general wear and tear. A label displaying my contact details was added to the front of the device, to allow for the devices to be returned if found by a resident. Total cost for these backpack devices was estimated at AUD$250 ($70 for the i-gotU, $170 for a VHF transmitter, and $10 for additional items). Both types of GPS devices were programmed to record a fixe every 15 minutes. The GPS collars were also programmed to only record a fix if the horizontal dilution of precision (HDOP) was less than three; a lower HDOP value indicating a more accurate fix. However, the backpack devices recorded a fix without an indication of relative accuracy. This caused some units to record several fixes that appeared illogical in relation to distance between points. These identified incorrect fixes were removed before data analysis began.

5.2.4 Data analysis

Data was primarily analysed in ArcMap (Version 10.4.1). A property boundary layer in ArcMap was used to determine property usage by kangaroos and occurrence inside/outside of the urban boundary. Kangaroo home range size was analysed using the Home Range Extension software (Rogers et al., 2007) in ArcMap. Home range size was calculated through a 95% minimum convex polygon (MCP), which excludes the outer 5% of fixes from the harmonic mean. A 50% MCP was also calculated to determine the core area for individuals.

I used Spider Tools (version 9.2) in ArcMap to calculate distance from each GPS point to each house in Heritage Park (which was manually assigned a coordinate in ArcMap). However, as I was only interested in the distance to the closest house for each GPS point, I used pivot tables within Microsoft Excel (Office 2013) to filter distances. For each tracked individual, distances were averaged per hour, per day and then averaged in time intervals. To give an indication of house proximity for peri-urban GPS fixes only, I removed fixes recorded in the state forest beyond the peri-urban limit. Hourly movement rate was determined by calculating the distance between UTM coordinates for each GPS fix, using the following Excel formula:

$$= \text{SQRT}(((N1-N2)^2)+((E1-E2)^2))$$

Where ‘N1’ = northing 1; ‘N2’ = northing 2; ‘E1’ = easting 1; and ‘E2’ = easting 2. Distance moved was then calculated for each hour for each day, and then averaged per time interval per day. The time intervals I used were to match periods of interest relating to human activity. For both analyses, R studio (version 0.99.903) was used to determine statistical differences between ‘animal’ and ‘time interval’ using a 2-way ANOVA. Post-hoc Tukey comparisons of means was used to determine where differences occurred between animals and time intervals, as well as within animals. When testing for significance, I controlled the family-wise error rate using the Bonferroni correction. This created a new critical value derived by dividing the family-wise error rate of 0.05 (the default in R) by the number of tests. In the case of testing for significance between individuals and time intervals, the Bonferroni corrected level of significance was 0.0002. When testing for the significance between time intervals, the Bonferroni corrected level of significance was 0.003.

5.3 Results

5.3.1 Technical details

Four adult male kangaroos were tracked using GPS collars and 13 (including three of the collared kangaroos) were tracked using the drop-off backpacks (Table 5.1). The collars were deployed for a total of 63 days each. Deployment for the backpack devices ranged from 1 to 11.5 days (mean ± SE = 4.4 ± 1). The collars obtained between 68% and 71% of expected fixes, with fixes of > 3 HDOP not recorded (Table 5.1). Median HDOP was 1.8 to 1.9 and the median number of satellites obtained was five for all animals (Table 5.1). Fix rate success was > 90% for all backpack devices, except for one animal (Bumblebee; 89%) (Table 5.1).

Table 5.1. Technical details of tracked kangaroos at Heritage Park, including both collar and backpack GPS devices. Collars only recorded a fix if the HDOP was < 3. I-gotU devices did not record HDOP or number of satellites.

Animal name	GPS device	Date deployed	Days tracked	Total GPS fixes	GPS fix success (%)
Luke	Collar	20-07-16	63	4256	70
Han	Collar	20-07-16	63	4133	68
Chewy	Collar	20-07-16	63	4312	71
Lando	Collar	20-07-16	63	4254	70
Bumblebee	Backpack	28-07-16	11.5	984	89
Starkey	Backpack	08-06-16	11.1	1019	95
Ironhide	Backpack	28-07-16	6.3	586	98
Megatron	Backpack	28-07-16	6.2	564	95
Chewy	Backpack	21-09-16	4.8	417	90
Luke	Backpack	21-09-16	3.7	344	96
George	Backpack	08-06-16	2.8	261	99
John	Backpack	09-06-16	2.5	236	97
Han	Backpack	21-09-16	2.4	215	94
Paul	Backpack	08-06-16	2.1	195	97
Keith	Backpack	09-06-16	1.5	134	97
Roger	Backpack	09-06-16	1.3	121	96
Optimus	Backpack	28-07-16	1.0	89	94

5.3.2 Did kangaroos leave Heritage Park?

Nine kangaroos recorded fixes outside of Heritage Park. Three of these (all backpacks) were recorded in the adjacent peri-urban locality of Avocado Heights. They included 'Ironhide' (96% of total fixes), 'Paul' (71%) and Roger (29%). The other six (four collared, two backpacks) were recorded in the state forest surrounding Heritage Park. However, total fixes were > 1 % for only four kangaroos (Table 5.2). 'Han' and 'Lando' had the largest percentage of fixes recorded in the forest. The percentage of fixes was highest between 0900 and 1500 for 'Han', and between 1800 and 0600 for 'Lando' (Table 5.2). Only 4% of total fixes for 'Luke' were recorded in the forest. 'Bumblebee' was the only non-collared animal to record >1% of fixes in the forest surrounding Heritage Park.

Table 5.2. The proportion of fixes recorded in the state forest surrounding the Heritage Park urban boundary (to the south and west).

	Proportion (%) of GPS fixes in the forest surrounding Heritage Park					
Kangaroo	0000–0600	0600–0900	0900–1500	1500–1800	1800–2400	All fixes
Luke	3	2	4	7	4	4
Han	13	13	23	15	16	17
Lando	27	16	13	10	21	18
Bumblebee	9	14	13	12	16	13

5.3.3 Ranging area of kangaroos

Minimum convex polygons (MCPs) were created for each individual to represent their home range size (in hectares, ha) and core area (ha), relative to the peri-urban landscape (Figure 5.2) The overall mean home range size (95% MCP ± S.E; combined for both collars and backpacks) was 21.1 ± 4.2 ha across all kangaroos (Table 5.3). However, mean home range size was 34 ± 10.6 ha for collared kangaroos and only 15 ± 2.9 ha for backpack kangaroos. 'Han' (collared) had the largest home range which covered 24% of Heritage Park, with 35 properties occurring within its 95% MCP (Table 5.3). The mean percentage of Heritage Park within all kangaroos' home ranges was 7.7 ± 1.7% (Table 5.3). On average, 14.8 ± 2.0 properties occurred within a kangaroo 95% MCP (Table 5.3). The mean core area (50% MCP) combined for both collared and backpack kangaroos was 5.5 ± 1.3 ha. There was little difference in mean core are between collared (6.5 ± 3.6 ha) and backpack (5 ± 1.3 ha)

kangaroos. 'Starkey's (17 ha) and 'Han's (13 ha) core area were much higher than all other kangaroos. (Table 5.3). On average, kangaroo core area covered only 2.8 ± 0.8% of Heritage Park, with a mean of 5.9 ± 1.0% properties occurring within the core area of a kangaroo.

Table 5.3. Kangaroo home range (95% MCP) and core area (50% MCP) size (in hectares, ha), as well as the percentage of Heritage Park and number of properties occurring within each individuals MCP. For the kangaroos that were collared, their corresponding backpack data was not included in the total means.

	Area ranged (95% MCP)			**Core area (50% MCP)**		
Individual	Size (ha)	% of Heritage Park within MCP	Number of properties within MCP	Size (ha)	% of Heritage Park within MCP	Number of properties within MCP
Luke	19	8.9	10	4	2.1	3
Han	62	24.1	35	17	7.9	12
Chewy	16	8.4	15	2	1	3
Lando	39	12.3	17	2	1	3
Bumblebee	31	6.8	13	3	1.6	4
Starkey	27	14.1	26	17	8.9	18
Ironhide*	29	< 1	14	4	0	5
Megatron	20	10.5	23	9	4.7	8
Chewy^	5	2.6	5	2	1	3
Luke^	4	2.1	4	3	1.6	3
George	17	8.9	21	5	2.6	6
John	3	1.6	5	1	< 1	1
Han^	26	13.6	20	13	6.8	10
Paul*	14	3.1	15	3	< 1	7
Keith	5	2.6	7	2	1	3
Roger*	8	2.1	12	3	1.6	5
Optimus	6	3.1	10	3	1.6	6
Mean (±SE)	21.1 (±4.2)	7.7 (±1.7)	14.8 (±2.0)	5.5 (±1.3)	2.8 (±0.8)	5.9 (±1.0)

^Indicates that for individuals that were originally collared, this is their backpack data.
*Indicates that the individuals MCP overlapped with Avocado Heights, the number of properties within the MCP were still included.

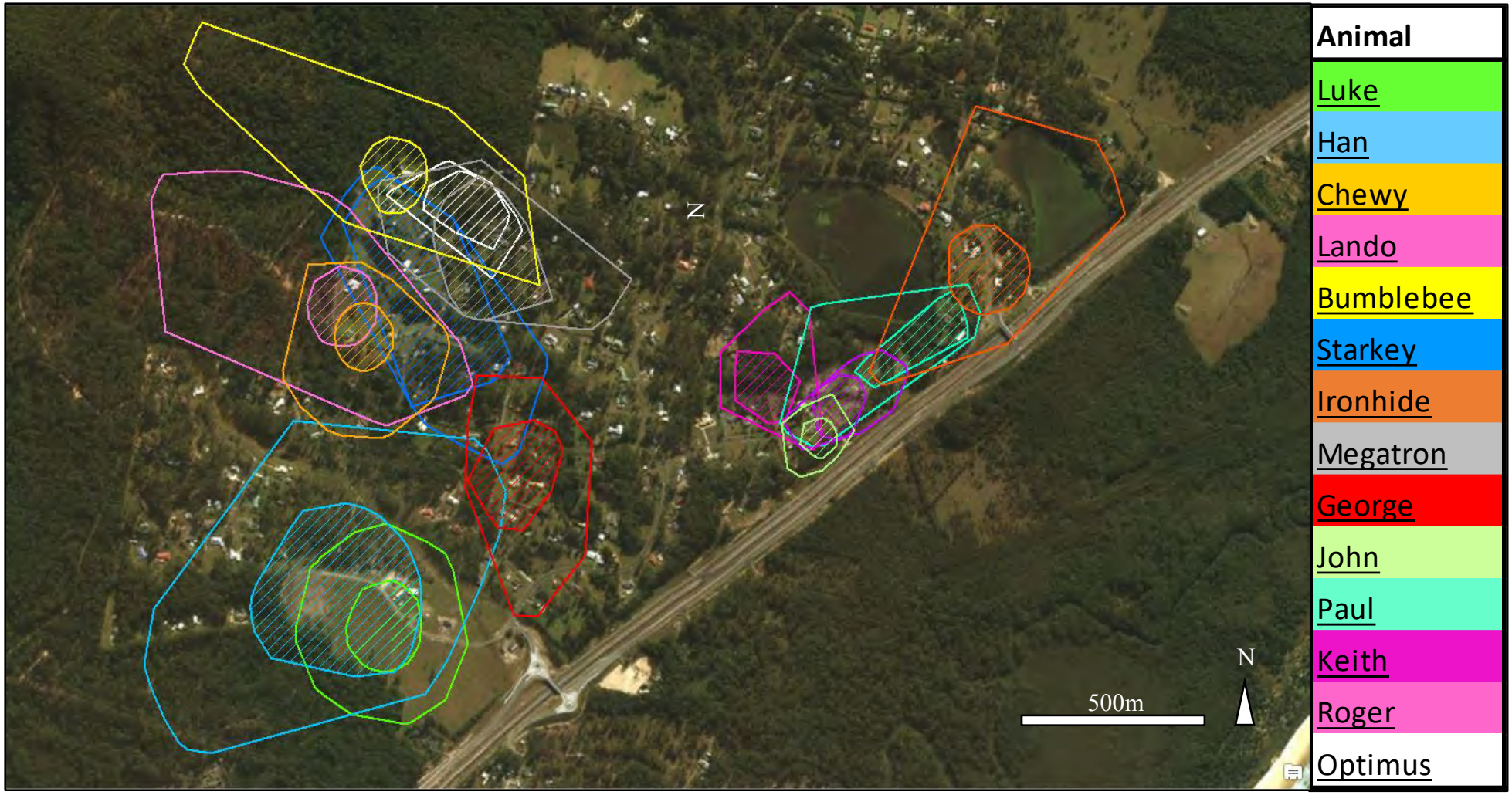

Figure 5.2. The 95% MCP (outer polygon) and 50% (inner, shaded polygon) for 14 kangaroos at Heritage Park. Note: the polygons for 'Luke', 'Han' and 'Chewy' backpack data were not included in this figure.

5.3.4 Property use by kangaroos

The mean number of properties used by kangaroos per day was 4.6 ± 0.5 properties (Table 5.4). Property use was highest in 'George', who used an average of 7.6 ± 1.8 properties a day, with a minimum of four, and maximum of 10 used in a single day (Table 5.4). The mean number of total properties used by kangaroos was 15.3 ± 1.8 properties, with 'Han' using the most properties at 34 (Table 5.4). Several kangaroos used more properties than what occurred within their 95% MCP. For example, 'Luke' used a total of 16 properties, but only 10 were within its 95% MCP, indicating that six occurred in the 5% not included in its home range.

Table 5.4. Property use for Heritage Park kangaroos; including mean and range per day, and total used during tracking period. Data on property use per day was not included for 'Keith', 'Roger' and 'Optimus', because tracking period was less than 2 days. For the kangaroos that were collared, their corresponding backpack data was not included in the total means.

	Properties used per day		Total properties used
Individual	Mean (SD)	Range (min-max)	
Luke	2.6 (1.1)	0 - 6	16
Han	2.6 (1.5)	0 - 7	34
Chewy	4.2 (1.3)	2 - 8	23
Lando	3.5 (1.5)	0 - 6	14
Bumblebee	5.2 (2.7)	0 - 8	11
Starkey	4.0 (2.2)	1 - 8	15
Ironhide*	4.6 (1.3)	3 - 7	16
Megatron	6.6 (1.1)	5 - 8	18
Chewy^	4.3 (2.1)	1 - 7	9
Luke^	2.4 (0.9)	1 - 3	4
George	7.8 (2.6)	4 - 10	18
John	3.8 (1.3)	2 - 5	7
Han^	6.7 (4.0)	2 - 9	13
Paul*	3.7 (0.6)	2 - 5	13
Keith	-	-	8
Roger*	-	-	12
Optimus	-	-	9
Mean (±SE)	4.6 (±0.5)	-	15.3 (±1.8)

^Indicates that for individuals that were originally collared, this is their backpack data.
*Indicates that this individual occurred in Avocado Heights, property used was still determined.

5.3.5 Kangaroo proximity to houses

The four collared animals were the focus of the following analysis due to the large number of days they were tracked, allowing for a more robust analysis. There was a significant difference in the mean distance to the nearest house between kangaroos (F = 463.6, P < 0.001) (Figure 5.3). However, post-hoc comparison of means showed no significant difference between 'Chewy' and 'Lando' (P = 0.906) and significant differences between all other combinations (all P values < 0.001). Further comparisons looked at where differences occurred between time intervals for each animal. This revealed that 'Luke' was significantly further away from the nearest house between 0600 and 1200; and significantly closer to the nearest house between 1500 and 1800 (Table 5.5). Post-hoc comparisons of means showed that 'Han' was significantly further away from the nearest house between 2100 and 1500; and significantly closer between 1800 and 0600 (Table 5.6). For both 'Chewy' and 'Lando', there were significant differences between time intervals with respect to proximity to houses (all P-values > 0.0002[Bonferroni corrected level of significance]).

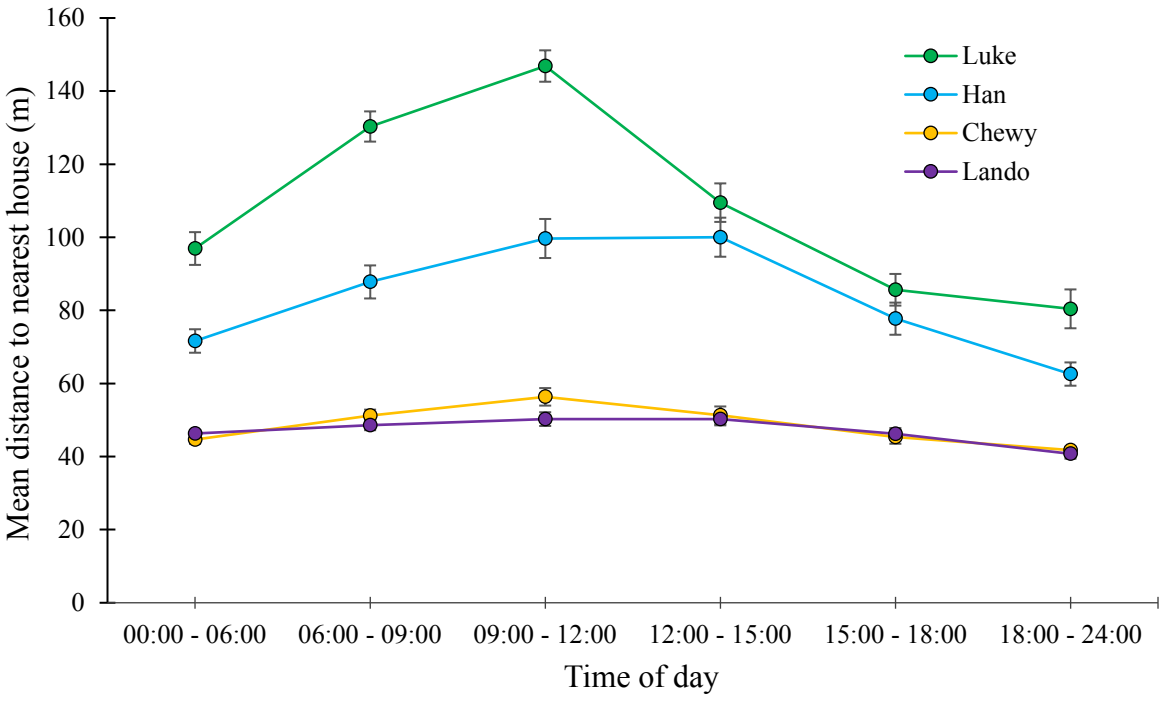

Figure 5.3. The mean distance to the nearest house for the four collared male kangaroos, with standard error bars. Time intervals were used to match human activity periods.

Table 5.5. Results of a post-hoc tukey comparisons of means, comparing time interval interactions for 'Luke'. The bonferroni corrected level of significance was 0.0002, therefore: * = $P < 0.0002$; ns = not significant.

Time	0000-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2400
0000-0600	-	*	*	ns	ns	ns
0600-0900	*	-	ns	ns	*	*
0900-1200	*	ns	-	*	*	*
1200-1500	ns	ns	*	-	*	*
1500-1800	ns	*	*	*	-	ns
1800-2400	ns	*	*	*	ns	-

Table 5.6. Results of a post-hoc tukey comparisons of means, comparing time interval interactions for 'Han'. The bonferroni corrected level of significance was 0.0002, therefore: * = $P < 0.0002$; ns = not significant.

Time	0000-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2400
0000-0600	-	ns	*	*	ns	ns
0600-0900	ns	-	ns	ns	ns	*
0900-1200	*	ns	-	ns	ns	*
1200-1500	*	ns	ns	-	ns	*
1500-1800	ns	ns	ns	ns	-	ns
1800-2400	ns	*	*	*	ns	-

5.3.6 Kangaroo movement rates

There was a significant difference in the rate of movement between kangaroos ($F = 26.60$, $P < 0.001$) and between time intervals for kangaroos ($F = 17.65$, $P < 0.001$) (Figure 5.4). Post-hoc comparison of means revealed no significant differences between 'Luke' and 'Han' ($P = 0.999$), and no significant differences between 'Chewy" and 'Lando' ($P = 0.413$). Post-hoc comparison of means also revealed that the 0600 to 0900 time interval was significantly higher than all other intervals except for the 1500 to 1800 interval (Table 5.7). Likewise, 1500 to 1800 was significantly higher than all other time intervals except 0000 to 0600, and 0600 to 0900 (Table 5.7). This indicates that across all kangaroos, a peak in movement rate occurred from 0600 to 0900, and to a lesser extent, 1500 to 1800. However, when interactions between time intervals for each individual animal was analyzed; there were no significant differences among 'Luke' or 'Han' (all *P*-values > 0.0002[Bonferroni corrected level of significance]), and only 0600 to 0900 being significantly different for both 'Chewy' and 'Lando' (Bonferroni *P*-values < 0.0002).

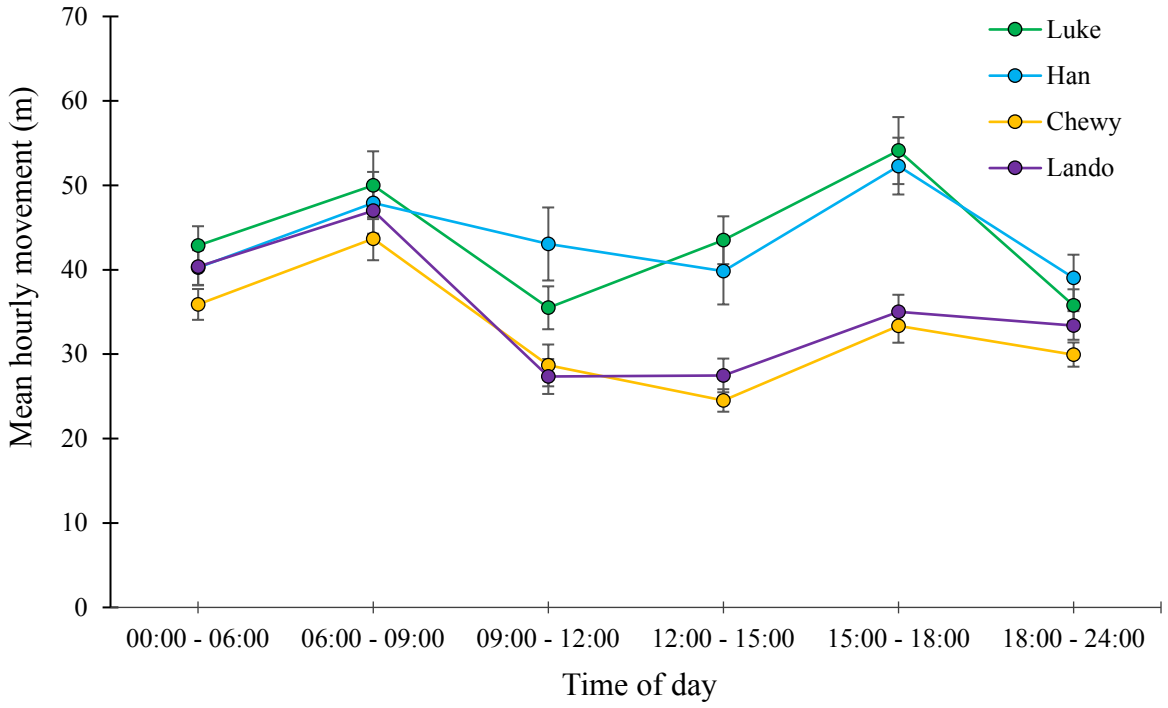

Figure 5.4. The mean distance to the nearest house for the four collared male kangaroos, with standard error bars. Time intervals were used to match human activity periods.

Table 5.7. Results of a post-hoc tukey comparisons of means, comparing time interval interactions. The bonferroni corrected level of significance was 0.003, therefore: * = $P < 0.003$; ns = not significant.

Time	0000-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2400
0000-0600	-	*	ns	ns	ns	ns
0600-0900	*	-	*	*	ns	*
0900-1200	ns	*	-	ns	*	ns
1200-1500	ns	*	ns	-	ns	*
1500-1800	ns	ns	*	ns	-	*
1800-2400	ns	*	ns	*	*	-

5.4 Discussion

This study showed that Heritage Park kangaroos interacted strongly with the peri-urban environment based on small range areas, high property usage and associated property fidelity, as well as spatial and temporal shifts in activity patterns. This study also showed the detail in which long term collars can obtain movement data, and the ease by which drop-off 'backpacks' can obtain short-term data, but across a larger number of replicates. There were no faults in the four collars.

Each collar recorded data for the desired deployment length and had a fix-rate success of about 70%. The 'i-gotU' backpack devices had a much higher fix-rate success, however they were not programmed to record HDOP or number of satellites. The capability of these devices in obtaining an accurate fix is uncertain. However, a study by (Forin-Wiart et al., 2015) indicated that low-cost GPS devices are relatively effective in obtaining accurate fixes when compared to commercially built GPS devices. The backpacks had varying degrees of deployment with the potential to last and record up to 12 days of data. Retrieval was also a complete success, with all 13 deployments retrieved and in working order. The cost of these backpacks allow for them to be used for a diversity of applications, especially in undergraduate or postgraduate research projects which often have tight fiscal constraints.

Heritage Park kangaroos generally occurred within the peri-urban matrix. However, minor forest use was recorded in the four collared individuals and in one of the backpack individuals. While it is unclear why some individuals used the forest, it is likely that the reason why kangaroos were predominately found in the peri-urban matrix is the high availability of resources and open spaces (Coulson et al., 2014). Our results suggest there are distinct groups of kangaroos throughout Heritage Park. For example, I have frequently observed a large group of kangaroos in the western corner of Heritage Park (see Figure 5.2), yet none of the tracked kangaroos were recorded here, despite no physical boundaries. Further research encompassing the entire Heritage Park kangaroo population may confirm the segregation of several groups throughout the site. Several monitored kangaroos were additionally recorded in the adjacent estate of Avocado Heights. As there is no defined boundary between the two estates, it could be construed that kangaroo populations from both Heritage Park and Avocado Heights overlap and are potentially part of the one, larger population.

Minimum convex polygons (MCP) provided an idea of the extent of peri-urban use by individuals and the areas and properties which they may potentially be interacting with. Mean home ranges and core area sizes of the four collared kangaroos were small, approximately half the size of estimates by Viggers and Hearn (2005) for *Macropus giganteus* home range size at the Tidbinbilla Nature Reserve. Similarities can also be drawn to urban white-tailed deer in North America, which tend to have home ranges that are less than 50% of those in rural areas (Rhoads et al., 2010). Kangaroos at Heritage Park were mostly sedentary, with few large-scale movements. Coulson et al. (2014) reported similar findings. However, adult males in their study exhibited strong sexual segregation during the non-breeding months. The extent of sexual segregation in adult male kangaroos at Heritage Park would require a longer-term study to include all seasons.

On average, almost 15 properties fell within each kangaroo's 95% MCP and six within their respective core areas. This indicates the number of properties which are potentially interacted upon by kangaroos, whether they be directly present on the properties or occupying areas near the properties. Property usage ranged from kangaroos using zero properties in a day to others using up to ten in one day. Each used, on average, close to five properties a day with 'George' averaging almost eight a day. Throughout tracking, kangaroos used on average 15.3 properties. Interestingly, mean total property usage was slightly higher than the mean number of properties within the kangaroos 95% MCP. This shows that property usage extended beyond the 95% MCP, indicating brief visits to several other properties. Throughout my fieldwork at Heritage Park, it became clear that residents believed that certain kangaroos would always be found on their property. My results suggest that the same kangaroo which frequently occupied a certain residential property, also frequently occupied several other properties. The high property usage and fidelity of kangaroos is important to consider when monitoring certain males or areas in Heritage Park for management.

The four collared kangaroos showed a spatial shift in their proximity to housing over the course of a day. In particular, 'Luke' and 'Han' were closest to the nearest house from early evening to early morning. This indicates potential critical periods for when people are more likely to encounter kangaroos, such as returning from work or school, hanging out washing, putting the garbage bin out etc. However, this is only a representation for two individuals and the same cannot be extrapolated to all kangaroos without more replicates. While no significance differences were seen within time intervals for both 'Chewy' and 'Lando', their pattern of house proximity was still similar to the other two. The obvious reason for differences in the extent of house proximity are the areas in which these four individuals occupy. 'Luke' and 'Han' occurred in an area which has a mix of properties and vacant blocks. This suggests that, given the option, these two individuals preferred to occupy the vacant areas during the day and specific properties during the night. 'Chewy' and 'Lando' did not have nearby vacant blocks to occupy, instead occurring on large front lawns of several properties which can only be accessed by a private driveway. Despite this, kangaroos were still slightly closer to houses during the night. The reasons why these four individuals moved closer to housing during the night is unclear. One possibility is that this may be related to the avoidance of predators if they rested in the forest.

The mean hourly rate of movement for these kangaroos also appears to correspond with the shift in house proximity, particularly for 'Luke' and 'Han'. While there were significant peaks in movement rates, differences were minimal across time intervals. Their spatial and temporal shifts over a day are an important management consideration, especially with regard to potential vehicle collision. Inwood et al. (2008) reported on vehicle collisions with kangaroos in Anglesea, which

usually occurred yearly and at most times of the day. The movement rates of Heritage Park kangaroos suggest that while small peaks were evident, the potential for vehicle collisions is similar throughout the day. This in particular is the case for ‘Luke’ and ‘Han’, who were constantly crossing the road between the vacant blocks and residential properties.

This chapter provided a new insight into kangaroo movement patterns in Heritage Park, which can be incorporated into localized management decision making to minimize potential negative interactions with residents. This information can also be used as an initial benchmark on how kangaroos utilize the peri-urban landscape on a day to day basis.

Chapter 6: Living with kangaroos, a look to the future

The eastern grey kangaroo is an aesthetic element to various towns on the NSW east coast. Many residents of the Coffs Harbour Northern Beaches have the privilege of sharing their livelihoods with these native macropods, and interacting with them on a day to day basis. Unfortunately, the large numbers of kangaroos and the continually expanding communities have resulted in increasing kangaroo related incidents. This thesis provides a significant contribution to the understanding of peri-urban kangaroo ecology and human perceptions towards them. My research will hopefully assist in the comprehensive management of peri-urban kangaroos towards the goal of a positive co-existence of people with a sustainable population of wild kangaroos.

The results of this study show that kangaroo densities were considerably high in the Coffs Harbour Northern Beaches region, especially at Heritage Park (1.6 ha^{-1} to 2.0 ha^{-1}), the Emerald Beach headlands (2.3 ha^{-1} to 4.9 ha^{-1}) and at the Safety Beach golf course (1.6 ha^{-1} to 2.3 ha^{-1}), with Heritage Park supporting a population of over 300 kangaroos. Community perceptions towards kangaroos were generally positive. However, there were concerns for potential conflict and vehicle collisions with kangaroos. Results also showed that kangaroos interacted strongly with the peri-urban environment, with high property usage and close proximity to houses during the night.

There are many aspects of this research that can be built upon to further drive the management effectiveness of peri-urban kangaroo populations. As this study only sampled kangaroos over a year, it would be worthwhile to continue regular counts to see how the various populations in the hotspot areas change, and if they are potentially at or near carrying capacity especially for Heritage Park, which has ongoing residential development. In addition to this, two of the tracked adult male kangaroos in this study made substantial use of current vacant blocks. It would be interesting to know how their activities change once these blocks become developed. As my study only targeted large males, incorporating females and younger males will provide a more detailed understanding on how the kangaroo populations utilize and behave within Heritage Park. Movement studies could also be expanded to the Safety Beach golf course to determine why male kangaroos appeared to have high site fidelity, in contrast to males at the Anglesea golf course in Victoria. Movement data may reveal minimal movements by these kangaroos at the golf course, or potentially larger scale movements which could indicate constant emigration or immigration of large males.

Future research on kangaroo movement is planned for several areas of the Coffs Harbour Northern Beaches, including Heritage Park and the Emerald Beach headlands, which will comprise GPS monitoring and identification tagging of kangaroos (Cathy Herbert, University of Sydney, pers. comm). This will hopefully lead to fertility control trials at these sites, which has successfully been trialed at other localities that support high numbers of peri-urban kangaroos (Cathy Herbert, University of Sydney, pers. comm). The decision matrix analysis in Chapter 2 outlined that fertility control is the most appropriate control option, as long as the public were positive towards it. While the majority of respondents did agree with sterilization, it was only marginal. However, it was evident too that there may have been a misinterpretation with the term 'sterilization' among residents, and that 'fertility control' may actually be more accepted. Before fertility control is implemented, it may be worthwhile to re-assess the communities' perception of this as a control method for kangaroo populations.

While the survey results were generally positive, there was a clear lack in both residents' exposure to kangaroo-related education and pertinent information from local authorities. This perceived deficiency in community engagement is already being addressed by the NPWS and CHCC through information stalls at various hotspots, and will also be a substantial component in the Coffs Harbour Northern Beaches Kangaroo Management Plan. Additional questionnaire surveys following the release of the plan will provide an idea of the effectiveness of the plan in tackling the key issues of education, management of kangaroo populations, and management of human-kangaroo interactions.

Throughout my research it became clear that human-kangaroo conflict is most likely related to the distribution of kangaroos in the urban area, rather than their abundance alone. For example, the Emerald Beach headlands and Safety Beach golf course had relatively high kangaroo densities. However, residents had overwhelmingly positive perceptions towards kangaroos with low concerns for conflict or vehicle collisions. The kangaroo populations are less commonly seen within the residential area, being concentrated on the headlands or golf course, and therefore reducing the likelihood of a higher number of direct interactions. In the case of Heritage Park where there is a high number of kangaroos and corresponding reports of incidents and concerns, management action urgent. The movement patterns of two of the collared kangaroos indicate that they had a strong preference for using vacant blocks, and I frequently observed high numbers of kangaroos on these vacant blocks during vehicle counts. However, when these blocks become developed kangaroos will likely concentrate more on unfenced properties, thus increasing the potential for human-kangaroo conflict. A suggestion for managing the dispersal of kangaroos in residential areas would be the inclusion of various 'kangaroo parks' or vacant areas dedicated to

allow space for kangaroos to occupy, similar to the situation seen on the golf course and headlands. By having several areas specifically for kangaroos, it could reduce the proximity of large groups of kangaroos to houses. This would require substantial landscape planning and management, however, I believe it is a suggestion worth considering.

In this age of urbanization, the occurrence of native species among human localities is likely to increase. I hope that my research will assist in achieving a scenario in which humans and kangaroos on the Coffs Harbour Northern Beaches can positively and sustainably co-exist.

"I feel very privileged to be able to sit on my deck and watch the interactions between the kangaroo population" – Woolgoolga Resident

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Appendix A: Kangaroo Community Survey

Dear Coffs Coast Resident,

I am seeking your participation in an online survey where you can share your experiences and opinions regarding Kangaroo interactions within your local residential area.
Coastal Kangaroos are an iconic image of the Coffs Coast region. Much of their range has become reduced, restricted or modified as a result of increasing urbanisation and the construction of the new Pacific Motorway. This has led to a perception of overabundance and increased threat of Human and Kangaroo conflict. Several government agencies are collaborating to develop a Kangaroo Management Plan to help Coffs Harbour residents and Kangaroos live safely together through positive interactions.
This survey is being carried out as part of an Honours project with the University of New England; in conjunction with the local National Parks and Wildlife Services and Coffs Harbour City Council. This survey is an important part of the Kangaroo Management Plan and has therefore been released to the entire Coffs Coast Region. In particular, we are interested in responses from the Northern Beaches where Human-Kangaroo interactions are frequent.

Aims of this survey

- **To engage the local community on their opinions, knowledge and attitudes towards Kangaroos in their local area.**
- **To assess public opinions and experiences to optimise safe living between Humans and Kangaroos in the Coffs Coast region**

The following survey is divided into several sections relating to different aspects of Human-Kangaroo interactions and management. Responses should be based on your personal experiences or opinions regarding Kangaroos in your local area.

I strongly encourage all residents of the Coffs Coast region to undertake this online survey. Please be aware that you must be over 18 years of age to participate. I thank you and would like you to encourage your family and friends from the Coffs Coast region to also participate in this survey.
The survey will take approximately 15 minutes to complete and is completely anonymous.

Contacts:

If you have any queries please contact either myself or my supervisors, A/Professor Karl Vernes and Dr. Raj Rajaratnam.

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Should you have any complaints concerning the manner in which this research is conducted, please contact the Research Ethics Officer:

Mrs Jo -Ann Sozou
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This project has been approved by the Human Research Ethics Committee of the University of New England (Approval No: HE15-321. Valid to: 01/01/2017)

I appreciate your time taken in reading this information and thank you for your participation in this online survey.

Kind regards,

Tim Henderson

Online Implied Consent for Participants

- **I have read the information contained in the Information Sheet for Participants and any questions I have asked have been answered to my satisfaction.**
- **I agree to participate in this activity, realising that I may withdraw at any time.**
- **I agree that research data gathered for the study may be published, and my identity will be unidentifiable due to the strict confidentiality explained in the information sheet.**
- **I am over 18 years of age.**
- **In preservation of anonymity, I understand that no name or signature is required of me to give consent. By activating the proceed button below I am agreeing to participate in this study.**

PROCEED TO STUDY

1. What is your age?

- ○ 18 to 24
- ○ 25 to 34
- ○ 35 to 44
- ○ 45 to 54
- ○ 55 to 64
- ○ 65 to 74
- ○ 75 or older

2. What is your gender?

- ○ Female
- ○ Male

3. Are you currently, or have you ever been a registered wildlife carer?

- ○ Yes
- ○ No

4. Do you identify yourself as:

- ○ Rural
- ○ Urban
- ○ Coastal
- ○ Unsure

5. Years lived at current address?

- ○ Less than 1 year
- ○ 1 to 2 years
- ○ 2 to 3 years
- ○ 3 to 4 years
- ○ 4 to 5 years
- ○ 5 to 6 years
- ○ 6 to 7 years
- ○ 7 to 8 years
- ○ 8 to 9 years
- ○ 9 to 10 years
- ○ 10 or more years

7. Current Residential Area

NOTE: Throughout this survey, your 'Local Area' refers to your Current Residential Area.

8. Have you previously lived in an area within close proximity to Kangaroos?

- Yes
- No

9. Were you aware of Kangaroos living in your local area before you moved there?

- Aware
- Unaware

10. Do you feel that Kangaroos in your local area have a positive or negative impact on:

	Positive	Negative	N/A
Your quality of life			
Your local environment			
Your appreciation for native wildlife			

11. Have you seen or seen signs of Kangaroos on your property within the last month?

- Yes
- No
- Unsure

12. How often do you see Kangaroos in your neighbourhood?

- More than once a day
- Once a day
- Once a week
- Less than once a week

13. At what time do you usually see Kangaroos in your neighbourhood? (select one or more)

- [ ] Morning
- [ ] Midday
- [ ] Afternoon
- [ ] Evening
- [ ] Night
- [ ] Never

14. If you see Kangaroos in your neighbourhood where do you see them? (select none to all)

- [ ] Your garden/lawn
- [ ] Your street
- [ ] Nearby garden/lawn
- [ ] Vacant blocks
- [ ] Open public spaces (such as headlands or parks)
- [ ] Unsure

15. If you see Kangaroos in your neighbourhood, what are they doing? (select none to all)

- [ ] Resting
- [ ] Feeding
- [ ] Drinking
- [ ] Hopping
- [ ] Unsure
- [ ] Other (please specify)

16. How many Kangaroos do you regularly see at once (e.g. in a mob), around your neighbourhood? (select one or more)

- [ ] 0
- [ ] 1
- [ ] 2
- [ ] 3
- [ ] 4
- [ ] 5
- [ ] 6 to 10
- [ ] 11 to 20
- [ ] More than 20

17. Which Kangaroos do you see the most in your neighbourhood?

- ○ Males
- ○ Females
- ○ Females with joey
- ○ Unsure

18. Do you believe Kangaroo populations in your local area are:

Too low	Somewhat low	About right	Somewhat high	Too high
○	○	○	○	○

19. Since living at your current address, do you believe Kangaroo numbers have:

- ○ Increased
- ○ Decreased
- ○ Stayed about the same
- ○ Unsure

20. Are you aware of important roles Kangaroos play in natural ecosystems, such as: Reducing the possibility of bushfires through grazing of dry grasses; and regenerating native grasses through feet and tails pushing seeds into the soil and urine and faeces acting as a natural fertilizer?

- ○ Yes
- ○ No

21. Are you concerned about the chance of collision between vehicles and Kangaroos in your local area?

- ○ Yes
- ○ No
- ○ Unsure

22. Within the last year, how many times have you been involved in a vehicle collision with Kangaroos in your neighbourhood?

- ○ None
- ○ 1
- ○ 2
- ○ 3 or more

23. Within the last year, how many times have you had to avoid hitting a Kangaroo on the road within your neighbourhood?

- ○ None
- ○ 1
- ○ 2
- ○ 3 or more

24. Within the last year, how many times have you been involved in a vehicle collision with Kangaroos in elsewhere the Coffs Coast region?

- ○ None
- ○ 1
- ○ 2
- ○ 3 or more

25. Within the last year, how many times have you had to avoid hitting a Kangaroo on the road elsewhere in the Coffs Coast region?

- ○ None
- ○ 1
- ○ 2
- ○ 3 or more

26. Which of the following would you suggest to reduce motor vehicle incidents with Kangaroos in your local area? (select none to all)

- ☐ Wildlife signs
- ☐ Speed humps
- ☐ Speed limit reduction
- ☐ Chicanes (a sharp, double-bend in the road)
- ☐ More road lights
- ☐ Roadside fencing
- ☐ Wildlife crossings (e.g. Underpasses/overpasses)
- ☐ Other (please specify)

27. Do you own Dogs?

- ○ Yes
- ○ No

28. If you answered 'Yes' to the above, are they generally:

29. Are you concerned about Dogs harassing or attacking Kangaroos?

- ○ Yes
- ○ No
- ○ Unsure

30. Do you believe restrictions should be placed on Kangaroos or Dogs, to reduce interactions between the two?

- ○ Kangaroos
- ○ Dogs
- ○ Both
- ○ Neither
- ○ Unsure

31. Do you think kangaroos are protected:

- ○ Everywhere in NSW
- ○ Only inside National Parks
- ○ Only in areas of natural bushland
- ○ Only where they occur outside of urban or semi-urban areas
- ○ Unsure

32. In your local area, would you prefer there to be:

- ○ Free-roaming Kangaroos
- ○ Kangaroos, but not on properties or roads
- ○ No Kangaroos at all
- ○ Unsure

33. Which Kangaroos would you consider to be aggressive or of concern to you? (select one or more)

- ☐ Large adult male
- ☐ Adult female with joey or juvenile
- ☐ Juvenile
- ☐ None
- ☐ Other (please specify)

34. For a Kangaroo that has attacked a person, what should the best outcome be?

- ○ Euthanasia
- ○ Relocation
- ○ Nothing
- ○ Unsure
- ○ Other (please specify)

35. How should Kangaroos that appear aggressive or threatening be managed?

- ○ Euthanasia
- ○ Relocation
- ○ Nothing
- ○ Unsure
- ○ Other (please specify)

36. Which of the following methods for controlling kangaroo numbers do you NOT agree with? (select none to all)

- ☐ Culling
- ☐ Euthanasia
- ☐ Relocation
- ☐ Sterilisation
- ☐ Fencing

37. Are you aware of any diseases that affect Kangaroos?

- ○ Yes
- ○ No

38. Have you seen any Kangaroos with signs of diseases in your local area?

- ○ No
- ○ Yes (please specify or type 'unsure')

39. Are you concerned about Kangaroos as a disease risk to people?

- ◯ Yes
- ◯ No
- ◯ Unsure

40. Are you concerned about potential conflict between yourself and Kangaroos in your local area?

- ◯ Yes
- ◯ No
- ◯ Unsure

41. In order from 1 to 4, which interactions are you most concerned about? (1 being highest concern, 4 being least concerned)

☐	Kangaroos attacking Humans
☐	Humans attacking Kangaroos
☐	Dogs attacking Kangaroos
☐	Kangaroos attacking Dogs

42. Do you feed or know someone in your area who feeds wild Kangaroos?

- ◯ Yes
- ◯ No

43. Do you think it is a good idea for people to feed wild Kangaroos?

- ◯ Yes
- ◯ No
- ◯ Unsure

44. Do you believe tourists interacting with Kangaroos as part of ecotourism is important?

- ◯ Yes
- ◯ No
- ◯ Unsure

45. If attacked by a Kangaroo, would you most likely:

- ○ Run away
- ○ Fight back
- ○ Curl into a ball
- ○ Drop to the ground and crawl away
- ○ Call for help
- ○ Do nothing
- ○ Unsure

46. If reporting an aggressive kangaroo, who would you likely contact? (select one or more)

- ☐ NPWS (National Parks and Wildlife Services)
- ☐ WIRES (NSW Wildlife Information, Rescue and Education Service)
- ☐ CHCC (Coffs Harbour City Council)
- ☐ RSPCA
- ☐ The Police
- ☐ Unsure

47. Do you feel informed from the local National Parks and Wildlife Services and Coffs Harbour City Council about what to do and what not to do when around Kangaroos?

	Highly uninformed	Somewhat uninformed	Neutral	Somewhat informed	Highly informed
Local NPWS	○	○	○	○	○
CHCC	○	○	○	○	○

48. Are you aware of the NPWS 'Living with Kangaroos' school based educational program?

- ○ Yes
- ○ No

49. If you answered 'Yes' to the above, do you believe this program has assisted in children understanding: (select one or more)

- ☐ The issues of living with kangaroos?
- ☐ How to respond to a Kangaroo attack?
- ☐ Neither
- ☐ Unsure

50. Have you been exposed to any other educational materials relevant to Kangaroo management issues?

- ○ No
- ○ Yes (please specify or type 'unsure')

51. Should people who move into an area with wildlife, such as Kangaroos, be provided with appropriate information on how to live with these animals?

- ○ Yes
- ○ No
- ○ Unsure

52. If you were/are a new homeowner, would you accept a Kangaroo Covenant (agreement) as part of your purchase, to apply Kangaroo mitigation measures such as fencing or reduced lawn area (i.e. more garden plantings)?

- ○ Yes
- ○ No
- ○ Unsure

53. Overall, how do you feel about your interactions with Kangaroos in your local area?

Positive interactions	Somewhat positive interactions	Neutral interactions	Slightly negative interactions	Negative interactions
○				○

Feel free to leave any additional comments relating to Kangaroos and Kangaroo related issues in your local area.

If you would be willing to participate in any future surveys on Kangaroo management issues in Coffs Harbour and the northern beaches, please provide your e-mail address (otherwise leave blank).

I greatly appreciate your participation in this important survey. Your input is highly valued and will be useful in optimizing appropriate management strategies for Kangaroo related issues in your local area.

Please encourage your family and friends in the Coffs Harbour area to also participate in this survey.

Thanks again,
Tim Henderson.
Honours Student,
The University of New England, NSW.

Please click 'Finish' to submit your responses