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The reproductive biology and temporal distribution of a great egret and nankeen night heron colony at the Perth Zoo

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The Reproductive Biology and Temporal Distribution of a Great Egret and Nankeen Night Heron Colony at the Perth Zoo.

By

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USE OF THESIS

Abstract

A colony of Great Egrets (*Ardea alba*) and Nankeen Night Herons (*Nycticorax caledonicus*) has existed at the Perth Zoo in Metropolitan Perth for over 25 years. The colony is particularly significant for the conservation and management of Great Egrets in Western Australia as it is the only colony located in the Metropolitan area. Baseline information of their breeding biology was needed to facilitate the development of management guidelines for the zoo colony. Foraging behaviour was used to highlight specific adaptations in hunting strategies and diet. However, it was not possible to observe foraging Nankeen Night Herons as they forage at night. Therefore, another species, the Little Egret, was selected to highlight specific adaptations.

From 1997 to 1999 the reproductive biology of the Great Egret and Nankeen Night Heron was assessed. The number of Nankeen Night Herons nesting at the Perth Zoo from 1996 to 1998 increased, while the number of Great Egrets declined. Both species nested in tall trees but only Great Egrets were specific in their choice of nesting tree species. Horizontal nest placement appeared to be influenced by body size. Great Egrets had a larger clutch size than the Nankeen Night Heron, and a slightly higher offspring mortality rate. There was some indication that Great Egrets may use the colony as an information centre about productive feeding grounds.

Foraging behaviour of Great Egrets and Little Egrets was recorded at six wetlands in the Perth Metropolitan area. Great Egrets were found to be mainly searchers, using 'stand and wait' and 'walk slowly' foraging behaviours, while the Little Egret was a 'pursuer', hunting by 'walking slowly', 'walking quickly' and 'pursuing prey'. Great Egrets

caught a greater number of prey per attempt at capture, feeding on larger sized prey, mostly fish. Little Egrets fed on smaller sized prey, mostly invertebrates. Habitat type and wind speed had a significant effect on striking success of Great Egrets. Cloud cover, wind speed and direction had a significant effect on striking success of Little Egrets. The larger body size of the Great Egret allowed them to forage in deeper water than the Little Egret.

Baseline information provided by this study has assisted in the development of management recommendations for the zoo colony and for Great Egrets and Little Egrets in the Perth Metropolitan area. To provide long-term information on overall population trends for the colony, regular counting and population distribution mapping of Great Egrets and Nankeen Night Herons is needed. To prevent Nankeen Night Heron numbers elevating and possibly encroaching on the nesting habitat of the Great Egret, food available in the zoo grounds should be reduced by covering caged animals' food. Planting of nesting trees within the existing colony may be required to enable the number of Great Egrets nesting in the Perth Zoo to increase. To prevent disturbances to birds when foraging within Perth wetlands, sites that are reachable by humans should be fenced off, or access restricted.

Declaration

I certify that this thesis does not, to the best of my knowledge and belief:

i. incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education;

ii. contain any material previously published or written be another person except where due reference is made in the text; or

iii. contain any defamatory material.

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Chapter 1 General Introduction

1.1 Wading Birds

Wading birds are those birds that wade in deep water, at the water's edge, or use other areas of wetlands (Soothill & Soothill 1982). Wading birds are a diverse group, with a wide range of body sizes and bill lengths that reflect their different feeding habits (Kushlan 1978a; Recher & Recher 1980). For example, long and thin bills are an adaptation for catching fast moving prey (e.g., Little Egret, *Egretta garzetta*), and large and thick bills allow birds to take larger and more solid prey (e.g., Nankeen Night Heron, *Nycticorax caledonicus*) (Kushlan 1978a; Recher & Recher 1980). Wading birds have many biological characteristics that make them attractive for study by ecologists and ethologists. They are usually easy to locate and observe because of their large size, conspicuous colours, their habit of foraging in aggregations and in open habitats, and taking large and easily identified prey (Kushlan 1981; Mock 1978). In addition, they nest in colonies that are often accessible and easily observed, and can accommodate more than one species (Kushlan 1981; Mock 1978).

Wading birds belong to the order Ciconiiformes, which contains medium to large, long-legged wading birds. This study concentrates only on wading birds as opposed to 'waders', that includes shorebirds. Five families make up the order, of which three are found in Australia: Ardeidae (herons, egrets), Ciconiidae (storks), and Threskiornithidae (ibises, spoonbills). As top-end piscivores, ardeids are of particular interest, because they can reflect ecosystem health, while their abundance, mostly diurnal habits and ease of approach make them especially suitable for study (Parnell *et al.* 1988). The Ardeidae are represented in Australia by six genera: herons and egrets (*Ardea*, *Butorides*, *Egretta*), night herons (*Nycticorax*) and bitterns (*Ixobrychus*, *Botaurus*) (Christidis & Boles 1994).

Egrets and herons use a variety of foraging behaviours and have long, kinked necks (Wade 1975) that enable them to capture fast moving aquatic prey, as the structure of the neck provides more force when striking. Many, such as the Great Egret (*Ardea alba*), are stalkers and generally move slowly or stand quietly in the water awaiting prey (Kushlan 1978a; Recher *et al.* 1983; Recher & Recher 1980; Slater 1987). Others, such as the Little Egret, forage actively and frequently pursue fast swimming prey (Recher *et al.* 1983). Long legs enable egrets and herons to hunt for prey in water of varying depth, and in damp places covered with short grass (Bell 1985; Marchant & Higgins 1990). They feed mostly on fish, amphibians and insects, although molluscs, crustaceans, reptiles, small birds and mammals are also taken (Barker & Vestjens 1989; Kushlan 1978a; Marchant & Higgins 1990; Recher *et al.* 1983; Recher & Recher 1980; Slater 1987).

The present study focuses on the Great Egret, Little Egret and Nankeen Night Heron. Each is common in southwestern Australia.

1.1.1 Great Egret, Little Egret and Nankeen Night Heron

The Great Egret (Figure 1) is the most urbanised of any large heron and has a cosmopolitan distribution (Hancock & Elliott 1978). Its feathers are white, and it can easily be distinguished by the following characteristics: large size (length = 90 to 120 cm); long neck (around 1.5 times the length of the body); long legs; thick, long, yellow bill; and a dark line that extends to well behind its eye (Hancock & Elliott 1978; Hancock & Kushlan 1984; Johnstone & Storr 1998; Marchant & Higgins 1990).

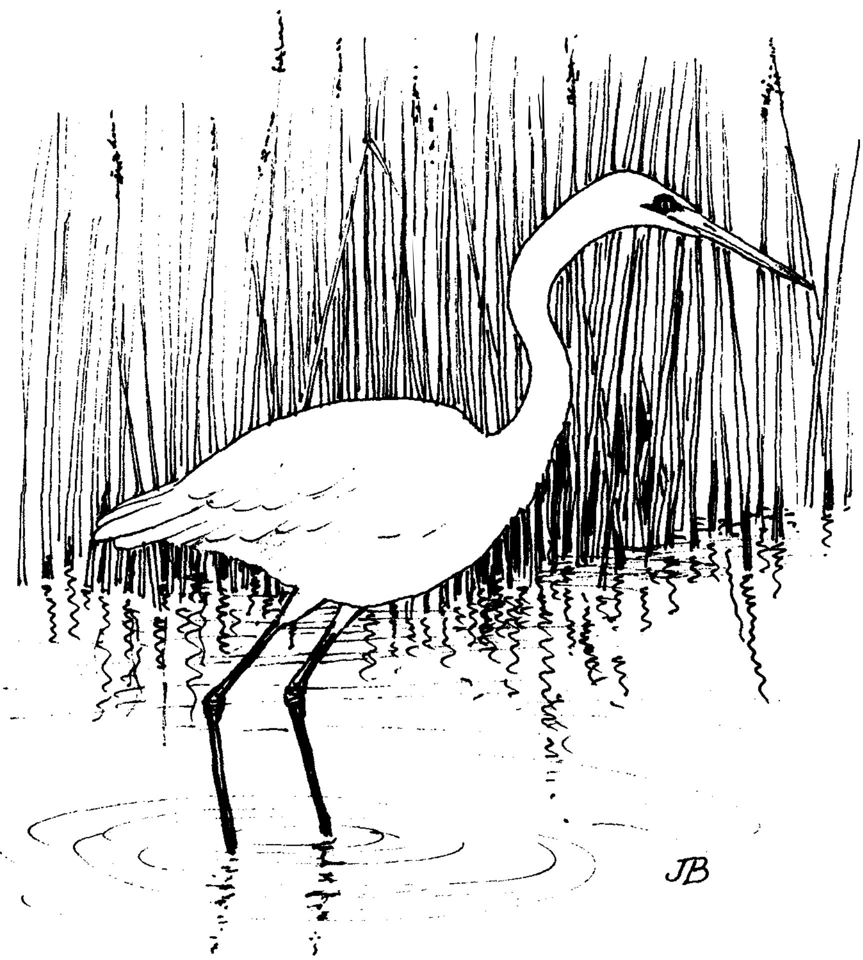

Figure 1. The Great Egret (*Ardea alba*).

The Little Egret (Figure 2) is found throughout Europe, Africa and Australasia. The very similar Snowy Egret (*Egretta thula*) occurs in North, Central and South America and is distinguished from the Little Egret by its smaller body size, all yellow feet and lores. The Little Egret has white plumage, but is distinguishable by its small size (length = 55 to 65 cm); shorter and thinner black to blue-grey bill, and short, black legs (Hancock and Kushlan 1984; Johnstone & Storr 1998).

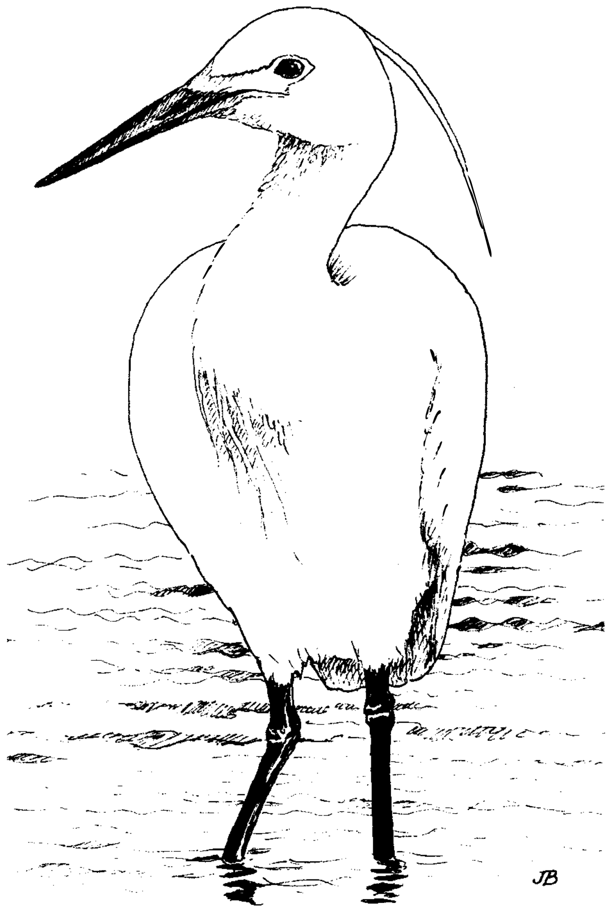

Figure 2. The Little Egret (*Egretta garzetta*).

The Nankeen Night Heron (Figure 3) is the Australasian equivalent of the Black-crowned Night Heron (*Nycticorax nycticorax*), which occurs throughout the rest of the world. The Nankeen Night Heron is a smaller bird than the Great Egret, averaging a body length of 59 cm, with a stocky, black bill (mean width = 1.1 cm ± 0.09, mean length = 13.0 cm ± 0.81, n = 20; Western Australian Museum (WAM) specimens measured by author) and short legs (mean length = 14.3 cm ± 1.09, N = 20; WAM specimens measured by author). It is easily distinguished from the egrets by the pale chestnut colour across the foreneck and upper breast. It has a black crown and nape, white underparts, and usually two long but simple, white nuptial plumes growing from the nape and drooping down the back. The Nankeen Night Heron is nocturnal, roosting during the day and hunting for food at night (Hancock & Elliott 1978; Hancock & Kushlan 1984; Johnstone & Storr 1998; Marchant & Higgins 1990). The nocturnal foraging habit of the Nankeen Night Heron makes observation difficult therefore few foraging data are available.

Figure 3. The Nankeen Night Heron (*Nycticorax caledonicus*).

1.2 Breeding Biology

Great Egrets in the southwest of Western Australia lay eggs from September to November and Nankeen Night Herons lay from September to December (Johnstone & Storr 1998; Storr 1991). Great Egrets and Nankeen Night Herons in Australia nest in a variety of native trees including *Melaleuca*, *Eucalyptus* and *Casuarina*, usually over water (Marchant & Higgins 1990). Nests of the Great Egret are bulky structures of sticks (Johnstone & Storr 1998) placed in trees from 4 to 13 m high. Nankeen Night Heron nests are loosely constructed from twigs and are usually situated on a horizontal branch of a tall tree. Nests are placed 4 to 15 m high. Clutch size of Great Egrets in Western Australia varies from 3 to 4 eggs, while clutch size of Nankeen Night Herons is usually 2 to 4 (Johnstone & Storr 1998).

In Western Australia, the Great Egret and Nankeen Night Heron breed in colonies, often interspersed with other species (Jaensch & Vervest 1989). Their habit of breeding colonially suggests colonial nesting offers advantages. Colonies may serve as meeting places for herons at the start of the breeding season (Butler, 1997). Wading bird colonies are thought to act as "Information Centres" for foraging trips (Bayer 1981; Butler 1997; Custer & Osborn 1978b; Erwin 1983; Forbes, 1989; Krebs 1974; Krebs 1978; Kushlan 1981; Pratt 1980; Ward & Zahavi 1973). Birds that have been unsuccessful in finding good feeding areas can gain information from successful neighbours. As food supply can often be temporary, fragmented and unpredictable, the ability of an individual to find food may be enhanced if it can follow successful individuals to good feeding areas. Colony members are at an advantage as there is more opportunity to observe other birds and follow them to good foraging grounds (Krebs 1974). Less energy is therefore expended in locating sites (Custer & Osborn 1978b).

In contrast, Forbes (1989) suggests that feeding advantages alone are not able to account for coloniality in ardeids. If the food supply is not temporary and unpredictable, there should be no advantage to living in a colony. Furthermore local competition for food may be increased by a higher density of birds. Pratt (1980) found no evidence at a Californian heronry that breeding adults followed others and suggests that flock departures may have been the result of coincidence, rather than birds using the colony as an information centre. Flocks may result from birds arriving, spending the same amount of time at the colony, and then departing at the same time. Arriving randomly and departing at the same time may have the appearance of departing as social flocks (Bayer 1981). Flocks may also induce the flight of others that are ready to leave the colony. The probability of several birds departing at the same time also increases with colony size (Bayer 1981). Departures may be synchronised with extrinsic factors such as tides (Bayer 1981), weather or time of day. Erwin (1983) after observing six species of egrets and herons near a major colony in coastal North Carolina, suggested that cues, including local enhancement and suitable water levels, played a more important role than did information sharing at the colony.

External factors, such as predators, human disturbance and weather, may have an adverse effect on bird colonies by affecting their clutch size, mortality rate and breeding success[1] (Vos *et al.* 1985). Wading bird colonies may be particularly susceptible to predators, as once located, chicks and eggs may be preyed upon over long periods resulting in complete failure of the colony (Parnell *et al.* 1988). For example, on one occasion at a colony at the Perth Zoo (Western Australia), almost all of the Great Egret chicks were predated by Nankeen Night Herons (Spence 1981). Krebs (1978), however, suggests that coloniality may act as an anti-predator mechanism where herons may be able to defend their young against predators and hence raise more young within a colony than when nesting alone. Butler *et al.* (1995) also found the probability of a breeding pair failing to raise young was over 2.5 times greater in small colonies of

Great Blue Herons (*Ardea herodias*) than larger ones. Forbes (1989) concluded that in situations where predation is frequent, group living is preferred and when relaxed, solitary living is favoured. Wading birds may also breed synchronously as an anti-predator mechanism (Krebs 1978), where predators are swamped with numerous young. Group mobbing of predators would presumably also be advantageous to breeding synchronously in colonies.

Recreational activities may disturb nesting and foraging birds. Colonial birds are particularly susceptible to disturbance by pedestrians, helicopters, canoes and motor boats (Carney & Sydeman 1999; Rodgers & Smith 1995). Vos *et al.* (1985) found that human activities caused Great Blue Herons to leave their nests. This resulted in increased mortality of young through exposure or predation, nest desertion, and colony abandonment. Herons, however, may habituate to repeated non-threatening activities (Vos *et al.* 1985). For example, Vos *et al.* (1985) found that when Great Blue Herons were subjected to intrusions by foot, a significant number temporarily abandoned their nest in the area closest to the intrusion, whereas a passing boat caused minimal response, with no herons flushed from their nests. Butler (1997) also reported a heron colony existing for many years despite being located within a former zoo near British Columbia, where huge numbers of people visited every year.

Nesting in tall trees may overcome some of the effect of predators and disturbance by making the birds inaccessible (Krebs 1978). This is typical of Great Egret and Nankeen Night Heron colonies (Fasola & Alieri 1992; Hancock & Kushlan 1984; Naugle *et al.* 1996). In contrast, Fasola and Alieri (1992) found that horizontal and vertical alignment of birds through vegetation correlated with body size. Larger heron species may nest at

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[1] Defined as the number of young fledged per successful nest (Maddock & Baxter 1991; Pratt & Winkler 1985)

higher levels because movement is easier among the tall and open branches, while smaller heron species may prefer lower elevations to attain greater protection from aerial predators. In both cases nesting in tall trees made them susceptible to adverse weather, as eggs or young may be blown out of the nest, or the nest may become dislodged. For example, Shepherd *et al.* (1991) found a 44% decline in the nesting effort of Great Egrets in South Carolina after hurricane 'Hugo' caused chick drowning, nest destruction, and abandonment of nests by adults. Burkholder and Smith (1991) also found an increase in mortality in Great Blue Herons from less than 3% in a year when there were no storms to over 25% in a year in which several major storms occurred.

Limited rainfall may have a detrimental effect on the clutch size and breeding success of wading birds. Bancroft *et al.* (1988) found that the quantity and timing of rainfall affects wading bird nesting success through influencing the availability of food. In a study on Great White Herons, Powell (1983) found that reproductive success appeared limited by food availability, as birds with supplemented diets had fewer nest failures, larger clutches, and produced more and slightly heavier young. Mock *et al.* (1987) suggested that the amount of food delivered by adults consistently influenced chick survival in egrets. Mock and Parker (1986) also found that food abundance may be a limiting factor in heron and egret survivorship, with reduced brood size at periods of low food availability.

1.3 Foraging Behaviour

Kushlan (1978a) summarises the foraging behaviour of wading birds into 38 behaviours (postures and actions) directed at obtaining prey. The use of different foraging behaviours is often correlated with prey or habitat variables and is therefore ecologically significant. For example, head movements are an important part of standing, walking and feeding where the head is tilted to prevent the glare from the sun interfering with the striking zone (Kushlan 1978a). Standing in an upright posture may act as an advertising display as well as allowing for a large viewing area (Kushlan 1978a). When standing erect, herons can 'scan' for prey located far away from the bird (Recher *et al.* 1983). Crouching, which reduces the field of vision, may bring the head closer to the strike zone (Kushlan 1978a). Recher *et al.* (1983) suggest that crouching may also be used for making the bird less conspicuous while stalking prey. Recher (1972) also observed a withdrawn crouch in Reef Herons (*Egretta sacra*) where they assumed a submissive posture when threatened or attacked. Neck swaying, where the neck is moved side to side, may provide a better estimate of prey distance and location, as well as enabling a quicker strike, as the muscles are already in motion when the strike begins (Kushlan 1978a). Foot stirring disturbs concealed or immobile prey (Kushlan 1976; Kushlan 1978a).

Morphology and behaviour are adaptations for foraging in specific habitats. For example, although the Great Egret favours areas of shallow water, it is able to hunt in deeper water than other wading birds such as the Little Egret and Nankeen Night Heron, due to its longer legs (Dimalexis *et al.* 1997; Recher & Recher 1980). Most large and medium-sized long-legged wading birds, such as the Great and Little Egret, typically feed while wading in shallow areas of open water or sparse vegetation. Dense and continuous vegetation may substantially reduce foraging opportunities (Bildstein *et al.* 1994).

Prey availability and prey density may contribute to differences in feeding behaviour (Erwin 1985). Wading birds have the ability to adapt their foraging method to minimise energy expenditure and increase foraging efficiency. For example, they may use 'stand and wait', and at other times 'search and pursue', depending on the prey available and the habitat in which they are foraging. Recher and Recher (1980) found the foraging repertoire of the Snowy Egret differed in that sometimes it was a searcher and other times a pursuer.

The diet of wading birds may also differ with the type of prey available and the habitat in which they feed. Wading birds have a catholic diet but may focus on the most abundant prey at a particular place and time. Prey that is more profitable, either because of its size or abundance, is usually selected (Cezilly *et al.* 1988; Recher & Recher 1980). King and LeBlanc (1995) found Snowy Egrets preferred to feed on recently moulted crawfish (*Procambarus* spp.) as they were easy to digest. They also found that Yellow-crowned Night Herons (*Nyctanassa violacea*), by standing with their shadow behind them, were able to target crawfish as they emerged from their burrows. Bray and Klebenow (1988) found that the White-faced Ibis (*Plegadis chihi*) in Great Basin Valley caught mostly earthworms as they were easy to capture and abundant. Oesophageal content analysis revealed that the birds were also consuming great amounts of soil. This caused an increase in the time spent feeding to make up for the loss in caloric intake. The ibis therefore preferentially fed in fields with surface water so they could wash the prey before consuming them.

Egrets, although generally solitary feeders (Hancock & Elliott 1978), often feed in aggregations with other wading birds (Davis 1985; Kushlan 1976; Kushlan 1978a;

Master *et al.* 1993; Miranda & Collazo 1997; Recher *et al.* 1983; Recher & Recher 1980; Willard 1977). Aggregations often form as a result of clumped or concentrated prey and may increase the birds' chance of locating prey and hence, increase foraging success. Master *et al.* (1993) found that actively foraging Snowy Egrets had a greater capture rate and capture efficiency when foraging in mixed species aggregations. Prey disturbance by other species increased the availability of fish that would normally seek refuge in the bottom mud. Conversely, Davis (1985) concluded that foraging White-faced Herons following Australian White Ibis (*Threskiornis molucca*) foraged less efficiently than when foraging alone. Although less energy was expended (fewer steps) by the heron when following the ibis, frequent hostile interactions between the heron and other herons were energetically expensive and time consuming.

1.4 The Perth Zoo Colony

Compared with other parts of the world, there is limited information on herons and egrets in Australia. In New South Wales, including Shortlands and the Hawkesbury River, studies have been undertaken on several species of egrets and herons, including the Great Egret, White-faced Heron (*Egretta novaehollandiae*), Cattle Egret (*Ardea ibis*), Nankeen Night Heron, Black Bittern (*Ixobrychus flavicollis*), Striated Heron (*Butorides striatus*), Intermediate Egret (*Ardea intermedia*) and Little Egret (Baxter 1988; Baxter 1994a; Baxter 1994b; Baxter & Fairweather 1998; Bridgman *et al.* 1997; Davis 1985; Geering 1993; Geering *et al.* 1998; Hindwood 1933; Kingsford & Johnson 1998; Lowe 1983; Maddock & Baxter 1991; McKilligan 1997; Recher & Recher 1980; Recher *et al.* 1983). A study of the Eastern Reef Egret was undertaken in Queensland (Recher & Recher 1980), while in Western Australia, a study of the distribution and size of Great Egret breeding colonies was undertaken in the south west (Jaensch & Vervest

1989).

In Western Australia, a colony of Great Egrets and Nankeen Night Herons has existed at the Perth Zoo in Metropolitan Perth for over 25 years. Only one study, however, which consisted of a count of nesting birds, has ever been undertaken on the colony (Jaensch & Vervest 1989). The colony is uniquely accessible and a major feature of the Perth Zoo. The zoo colony is particularly significant for the conservation and management of Great Egrets in Western Australia. It is the only colony of Great Egrets in the Perth Metropolitan area (Storey *et al.* 1993) and one of only nine colonies on the coastal plain, from Moore River to Busselton (Jaensch & Vervest 1989). In contrast, Nankeen Night Herons are abundant throughout Western Australia (Storr 1991), forming loose colonies that are situated throughout the southwest, often near egret colonies (Slater *et al.* 1994). They also nest elsewhere in the Perth Metropolitan area. For example, a small colony is found in a public park near central Fremantle (Singor 2001).

The zoo colony is the only known Great Egret colony in Australia that is situated in a zoo rather than in a wetland environment and that is a truly urban heronry. Further, the colony is under threat because of the deterioration and removal of nesting trees and loss and degradation of wetland foraging areas around Perth. Egrets require tall trees with easy access to foraging sites (Baxter & Fairweather 1998), which are generally located within a few kilometres of the nesting colony (Custer & Osborn 1978b). Urban development has restricted the number of sites where Great Egrets can nest and forage within the Perth region. Such threats may ultimately lead to the loss of the colony at the Perth Zoo and a significant decrease in the presence of Great Egrets on the Swan Coastal Plain. Night Herons take a wider range of prey (Hancock & Kushlan 1984;

Marchant & Higgins 1990; Slater *et al.* 1994) and therefore are probably more flexible in the choice of foraging area and nesting location.

1.5 Aims and objectives

In Western Australia, in particular, little is known about the foraging and reproductive biology of the Great Egret, Little Egret and Nankeen Night Heron. This research project aims to provide a basis for improving management at the Perth Zoo colony in order to ensure the long-term survival of the Great Egret and Nankeen Night Heron. Specifically, aims were:

- to examine the reproductive biology of Great Egrets and Nankeen Night Herons at the Perth Zoo colony.
- to examine the role of the zoo colony as an information centre.
- to examine the foraging repertoire of the Great Egret in a number of wetlands in the Perth Metropolitan area. The foraging behaviour of the Nankeen Night Heron was not examined due to their nocturnal habit. Therefore, another species, the Little Egret, was selected to highlight specific adaptations in their hunting strategies and diet. The Little Egret was selected based on its medium size and the ease with which it could be observed.
- to determine the long-term sustainability of the Perth Zoo colony of Great Egrets and Nankeen Night Herons.
- to produce management recommendations for the Perth Zoo colony as well as for Great Egrets and Little Egrets in the Perth Metropolitan area.

Chapter 2 The Perth Zoo Colony

2.1 Introduction

Heron and egret reproductive biology has been extensively studied in the Northern Hemisphere, particularly in North America (e.g. Frederick *et al.* 1992; Kelly *et al.* 1993; Pratt & Winkler 1985; Ranglack *et al.* 1991) and Europe (e.g. Campos & Fernandez-Cruz 1991; Dusi & Dusi 1987; Erwin *et al.* 1996; Fasola & Pettiti 1993; Kazantzidis *et al.* 1997; Post 1990; Pratt & Winkler 1985). Australian studies on heron and egret reproduction are limited.

Australian research on herons and egrets has largely focused on the impact of variables, such as rainfall, predation, and human impacts on breeding biology and nesting success. A positive correlation of rainfall with breeding success of Great, Intermediate, Little and Cattle Egrets in New South Wales has been found by Baxter (1994a), Geering (1993), and Maddock and Baxter (1991). In addition, McKilligan (1997) has modelled the effect of rainfall on breeding success of Cattle Egrets in Queensland through pasture growth and resulting growth in grasshopper and locust populations. Predation and humans have been shown to have a negative effect on nesting of egrets and herons. Baxter (1988) found a Wedge-tailed Eagle (*Aquila audax*) negatively impacted on Cattle Egret nesting in New South Wales. Kingsford and Johnson (1998) found that the building of dams and resulting diversion of water had a negative impact on nesting Intermediate Egrets and Nankeen Night Herons in arid Australia. Phillimore and Recher (1999) (Appended) noted the impact of disturbance to nesting Great Egrets resulting from nest and chick counts.

Other research on herons and egrets focuses on the survey and census of colonies. Baxter (1994b) described the location and status of Great, Intermediate, Little and Cattle Egrets in New South Wales. Morton *et al.* (1993) described the distribution and abundance of Great, Little and Intermediate Egrets in the Alligator Rivers Region, Northern Territory. Jaensch and Vervest (1989) mapped Great Egret breeding colonies in Western Australia. Great Egrets and Nankeen Night Herons have been nesting at the Perth Zoo for over 25 years. Only Jaensch and Vervest (1989) however, have counted the number of Great Egrets breeding at the colony. These counts were undertaken by the Royal Australasian Ornithologists Union (RAOU), from 1986 to 1988.

The aim of part of the present study was to examine the reproductive biology of the Great Egret and Nankeen Night Heron colony at the Perth Zoo, to facilitate the development of management guidelines to ensure their long-term survival. Nankeen Night Herons were excluded from foraging observations as they rarely venture from the colony during the day, due to their nocturnal feeding habit (pers obs.).

Hypotheses were as follows:

- The number of Great Egret and Nankeen Night Heron nests present at the Perth Zoo colony is dependent on yearly rainfall.
- Great Egrets and Nankeen Night Herons are non-selective in choosing nesting tree species at the Perth Zoo.
- Horizontal and vertical nest placement are dependent on bird size, where Great Egrets nest higher and further away from the tree centre due to their larger size.
- Great Egret and Nankeen Night Heron offspring mortality is dependent on daily temperature and rainfall.
- Great Egrets use colonies as information centres.

2.2 Methods

2.2.1 Study Site

The Perth Zoo is situated in South Perth along Labouchere and Mill Point Roads (Latitude 31.97430; Longitude 115.85344) (Figure 4). All Great Egret nests are located within the zoo grounds in pine trees (*Pinus canariensis*) (Figure 5). Nankeen Night Heron nests are scattered within the zoo grounds and are found in many different tree species, such as fig trees (Moreton Bay Fig, *Ficus macrophylla*; Port Jackson Fig, *Ficus rubiginosa*[2]) and pines (*P. canariensis*) (Figure 6). Nankeen Night Heron nests also were located outside the zoo grounds, along the same roads, but these were excluded from the study.

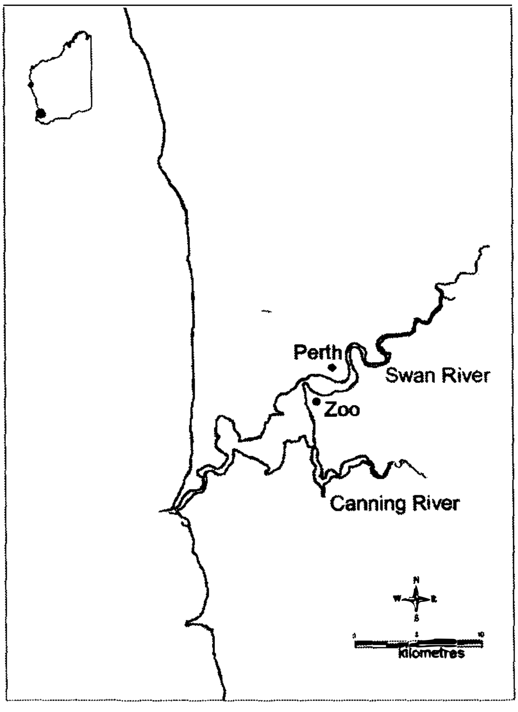

Figure 4. Map of Perth Metropolitan area showing location of Perth Zoological Gardens and Perth city.

[2] Tree species names were obtained from Thompson, J. and Crombie, I. (1998) Australian Bushwalk Flora Resource Material; Perth Zoo.

Figure 5. *Pinus canariensis* tree within the Perth Zoo containing nesting Great Egrets.

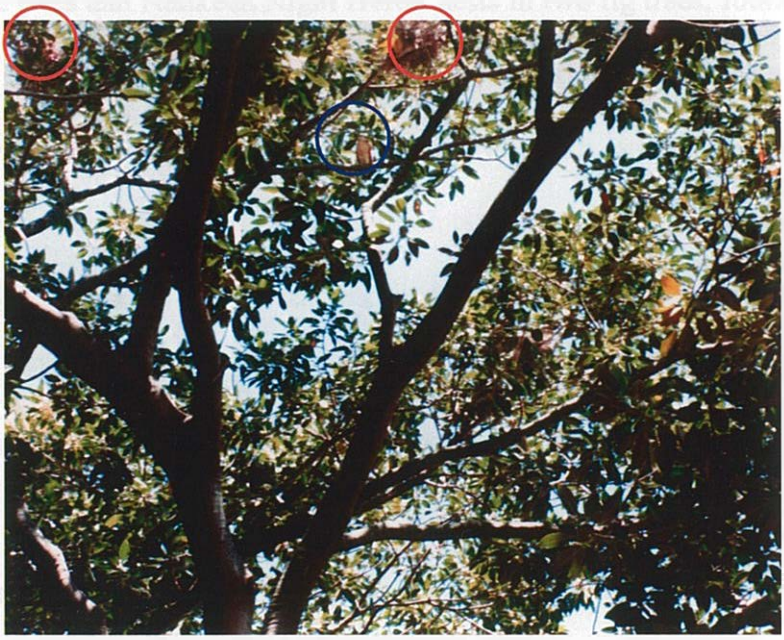

Figure 6. *Ficus* sp. tree within the Australian Bushwalk exhibit in the Perth Zoo containing Nankeen Night Heron nests (circled in red) and adult bird (circled in blue).

2.2.2 Nest Counts

Surveys at the Perth Zoo were conducted during the breeding season (September to December) in 1996/97, 1997/98 and 1998/99, to determine the number and dispersion of nesting Great Egrets and Nankeen Night Herons. Annual rainfall figures were obtained from the Bureau of Meteorology (measured at Perth Airport) and were compared with the annual number of Great Egret and Nankeen Night Heron nests recorded from 1996 to 1998. In each survey year, the tree species and location for each nest was recorded.

In 1996/97, 39 Great Egret and 14 Nankeen Night Heron nests that were visible from the ground, were selected for intensive study. This sample consisted of Great Egret nests in 28 pine trees and Nankeen Night Heron nests in two fig trees, found throughout the Australian Bushwalk exhibit. The aspect, location and distance of the nests within the nest trees was recorded. Aspect was recorded as north, south, east or west, with nests that were located between the cardinal points of the compass assigned half a nest to each direction. For example, a nest facing northwest was recorded as facing half north and half west. Nest location was recorded as either central or peripheral, and the distance from the centre of the tree was estimated.

The height of nests was measured using a clinometer. This method entailed measuring the distance between the observer and the tree such that the clinometer showed a 45° angle to the nest. This distance was equivalent to the nest height.

2.2.3 Reproductive Biology

In 1996, daily estimates from the ground were made of the number of Great Egret and Nankeen Night Heron chicks. This proved unsuccessful as both species nested in tall trees, some up to approximately 40 metres in height, which reduced visibility and made observation of the nests difficult. Therefore chicks could only be counted when they were bigger and visible above the rim of the nest and even then most chicks probably could not be seen. In the 1997/98 and 1998/99 breeding seasons a 30 metre high cherry picker was used to provide sufficient elevation to allow a more accurate count of the number of eggs and chicks to be made (Figure 7). The size (width and depth) of nests and nest construction materials used were recorded for two Great Egret and one Nankeen Night Heron nest that could be reached by the cherry picker for measurement.

Figure 7. Observers in Western Power cherry picker over *Ficus* tree (bottom left) containing Nankeen Night Heron nests.

Nineteen pine trees with nesting Great Egrets and 17 fig trees with nesting Nankeen Night Herons were selected for intensive study based on accessibility for the cherry picker. Selected pine trees were located in the Australian Bushwalk exhibit and the fig trees were along Mill Point Road. The nests were examined three times in 1997 (9 November, 23 November and 13 December) and again in 1998 (8 November, 22

November and 6 December) to determine the number of active nests and the number of offspring. The number of offspring was defined as the number of eggs and chicks found in each nest. As Great Egret and Nankeen Night Heron eggs were only counted on the dates the cherry picker was used, it is most likely that not all eggs laid were counted. Therefore the number of eggs is a minimum estimate of clutch size. Only nests that contained eggs or chicks were considered active and used to calculate means and survival rate. Although egg laying started for both bird species in September, counts were not undertaken until November to prevent disturbing the birds during laying. Counting was not undertaken after the 13 December, as the chicks were larger and more mobile, and therefore more likely to fall out of the trees if disturbed (Phillimore & Recher 1999, Appended). On the 6 December 1998, a green blanket was used to camouflage the cherry picker to test whether it would prevent chick deaths from occurring. However, this appeared to make no difference, chick mortality occurred and so the count ceased. As this count was incomplete it was not included in the calculations.

In 1997/98, daily searches around the base of nesting trees were made for chicks and eggs fallen from their nest, in order to calculate a minimum mortality rate. It was not possible to locate all dead offspring as often they were removed by zoo staff. Hence a 'minimum' estimate was made. Broken egg shells that contained large amounts of yolk indicated the death of an embryo. Live chicks were often found and if uninjured, were placed in a rearing pen. These chicks were recorded as mortalities as without human intervention they probably would have died. Injured chicks were euthanased by the zoo veterinarian and were also included in the mortality count. In 1998/99 surveys of dead offspring were reduced to four times, on 8 and 22 November, 6 December 1998 and 10

January 1999. Any observations of predation by animals (such as ravens and possums) on young chicks or eggs at the colony were also recorded.

To determine whether the colony was viable and reproducing at a rate that would sustain it (Baxter 1994a), breeding success was calculated. The breeding success can be determined by measuring the fledging rate or the number of young fledged per successful nest. A nest was considered successful if chick(s) developed to an age where they can fly to trees away from their nest (Maddock & Baxter 1991; Pratt & Winkler 1985). For this study, it was not possible to determine the fledging success as it is measured on a per nest basis. Apart from not being able to individually mark the nests, Great Egrets and Nankeen Night Herons were easily disturbed. Therefore any attempt to get close to the nests to band nestlings would have had a detrimental effect on the colony (Phillimore & Recher 1999; Appended). As the chicks aged, they became more mobile, which made it difficult to tell which nest the chick was from. Baxter (1994a) notes there is no way of determining 'true' breeding success without researchers disturbing the colony. Nest and egg marking have also proven to have a detrimental effect on the survivorship of young (Boellestorff *et al.* 1988). The survival rate was therefore estimated for the 1997/98 breeding season.

Percent survival was calculated by subtracting the number of dead found from the total number of offspring counted, dividing this by the total number of offspring and multiplying by 100. The survival rate per nest was calculated by subtracting the total number of dead from the total number of offspring counted and then dividing this figure by the total number of nests. The count of offspring included those visible from the cherry picker on 9 November 1997 (date at which highest number of offspring were counted) in 19 pine and 17 fig trees. The count of dead included the number of chicks and eggs found at the base of nesting trees. It is likely that some offspring were missed during counting and so a comparison of the number of offspring to the number of dead suggests a minimum survival rate. The survival rate per nest was then calculated by dividing the number of surviving offspring (total offspring minus the total number of dead) by the number of active nests visible from the cherry picker on 9 November 1997.

2.2.4 Banding

It was not possible to band adult or young Great Egrets and Nankeen Night Herons as most of the nests could not be reached and the chicks were easily disturbed. However, chicks that survived a fall from their nest and were abandoned by their parents, were hand-reared and individually marked with both a coloured and metal band (Figure 8). The coloured band was placed above the tarsus, and the metal band around the base of the tarsus. The wing also was marked prior to their release with Dy-Mark Stock Marker, a semipermanent, purple dye for identification in the field.

Figure 8. Juvenile Great Egret from Perth Zoo colony tagged with red band (right leg) and metal band (left leg).

2.2.5 Departure Patterns

Observations of Great Egrets departing from the colony were made three mornings a week before and during sunrise from October to November 1997. When egrets departed, the direction of travel was recorded using a compass, with the zoo colony as the centre point. To determine whether egrets were using the colony as an 'information centre', once an egret departed for the first time that day, the number of colony members and direction flown was recorded for the next two minutes. Other researchers have used different methods for measuring whether birds follow each other. Erwin (1984) and Wong *et al.* (1999) defined grouping as two or more birds flying in the same direction for at least 200 metres within 50 metres of each other. Krebs (1974) defined the existence of flocking as herons departing within five minutes and Pratt (1980), an interval of four minutes. Bayer (1981) considered this time too long to provide an indication of whether herons were part of the same flock and used a time interval of one minute to measure heron departures. For this study, more than two minutes would not have been possible because the zoo is surrounded by high-rise buildings and after two minutes the birds would not have been visible.

2.2.6 Statistical Analyses

Statistical tests on aspects of reproductive biology were performed using SPSS Statistical Package with a 5% significance level. Differences in breeding and nesting variables between Great Egrets and Nankeen Night Herons were analysed. Nest height and nest distance from the centre tree trunk were compared with bird species using a *t* test. Nest location was compared between bird species using a Fishers Exact test. No statistical analyses were performed on nest aspect as there were cells with an expected frequency of less than five. Fowler *et al.* (1998) state when using Chi-square analysis to compare observed and expected values, no more than 20% of the total number of expected frequencies should be below five.

*T*tests were used to test for differences between the number of offspring, eggs and chicks, and year (9 November 1997, 8 November 1998) for each bird species. As yearly nesting data were not independent, a more stringent alpha level of 0.001 was used to test for significance. *T*tests were also used to compare the number of offspring, eggs and chicks between bird species on 9 November 1997 and 8 November 1998 ($\alpha<0.05$). Counts obtained on 9 November 1997 and 8 November 1998 were used for both yearly and species analyses, as they were predominantly when the highest offspring counts were recorded.

To determine whether a relationship existed between weather conditions and the mortality rate of the Great Egret and Nankeen Night Heron, daily rainfall and temperature were compared to the mortality rate for the 1997/98 breeding season. Daily rainfall (millimetres) and temperature (degrees Celsius) data were obtained from the Bureau of Meteorology.

A *t*test was used to compare the number of dead offspring (eggs and chicks) counted in the 1997/1998 breeding season between Great Egrets and Nankeen Night Herons. Spearman Rank Correlations were used to test for a relationship between the number of dead Great Egret and Nankeen Night Heron offspring found in the 1997/98 breeding season and daily temperature and rainfall.

A Chi-square procedure was used to test for differences in the direction of departure between the initial Great Egret and following Great Egrets from the zoo colony. To prevent more than 20% of the total number of expected frequencies being below five, departure directions were analysed using the cardinal points of the compass (north, south, east, west). Directions that were located between the cardinal points of the compass were assigned half a count to each direction. For example, a departure in a northwest direction was recorded as half north and half west.

2.3 Results

2.3.1 Number of Nests

One hundred and thirty Nankeen Night Heron and 49 Great Egret nests were counted over the 1996/97 breeding season, 92 Nankeen Night Heron and 41 Great Egret nests in 1997/98, and 153 Nankeen Night Heron and 36 Great Egret nests in 1998/99 breeding season (Figure 9). Two pine trees containing five Great Egret nests and four Nankeen Night Heron nests were removed in 1997 to make room for new exhibits.

The relationship between the number of Great Egret and Nankeen Night Heron nests in the zoo colony from 1996 to 1998 and annual rainfall for the Perth Metropolitan area was examined (Figure 9). Rainfall was higher in 1996 (889 mm) and lower in 1997 and 1998 (653 mm, 684 mm). There appeared to be a general trend between annual rainfall and the number of Great Egret nests counted in the Perth Zoo from 1996 to 1998. There was no obvious trend in annual rainfall and the number of Nankeen Night Heron nests counted in the Perth Zoo from 1996 to 1998.

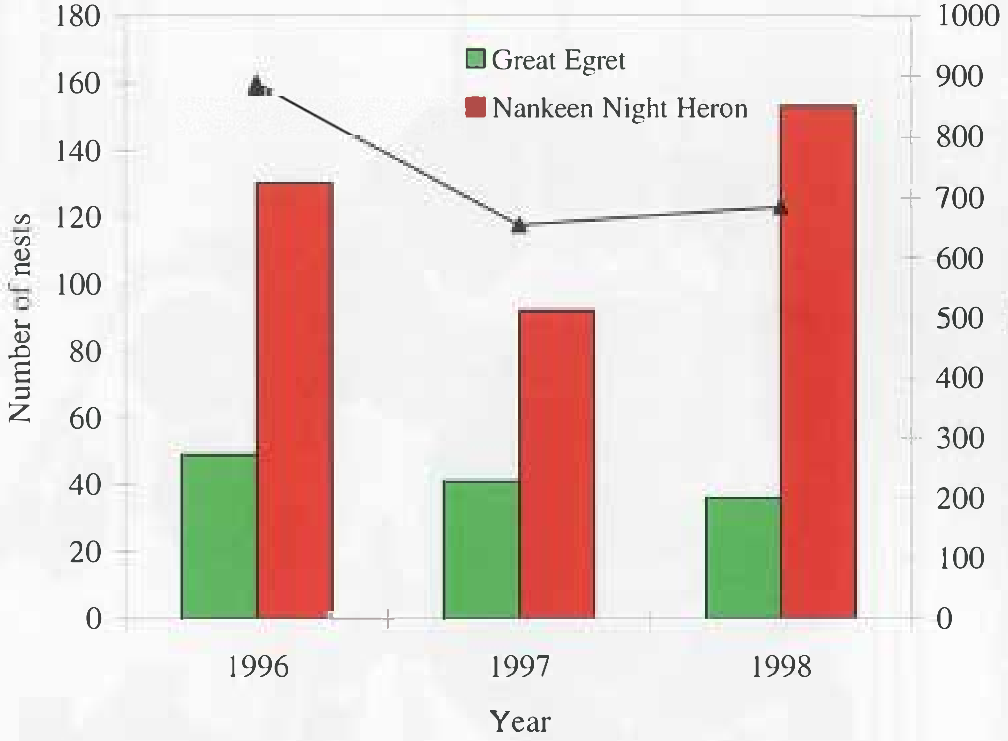

Figure 9. Number of Great Egret (green bars) and Nankeen Night Heron (red bars) nests at the Perth Zoo and annual rainfall (–), (obtained from Bureau of Meteorology, measured at Perth Airport) from 1996 to 1998.

2.3.2 Nest Site Characteristics

2.3.2.1 Nest Dispersion

All Great Egret nests were found in the Australian Bushwalk display, in the northeast section of the zoo. Nankeen Night Heron nests were scattered throughout the northern and eastern sections of the zoo grounds, including the Australian bushwalk display, picnic lawn, butterfly house, harmony farm and the elephant enclosure (Figures 10, 11, 12).

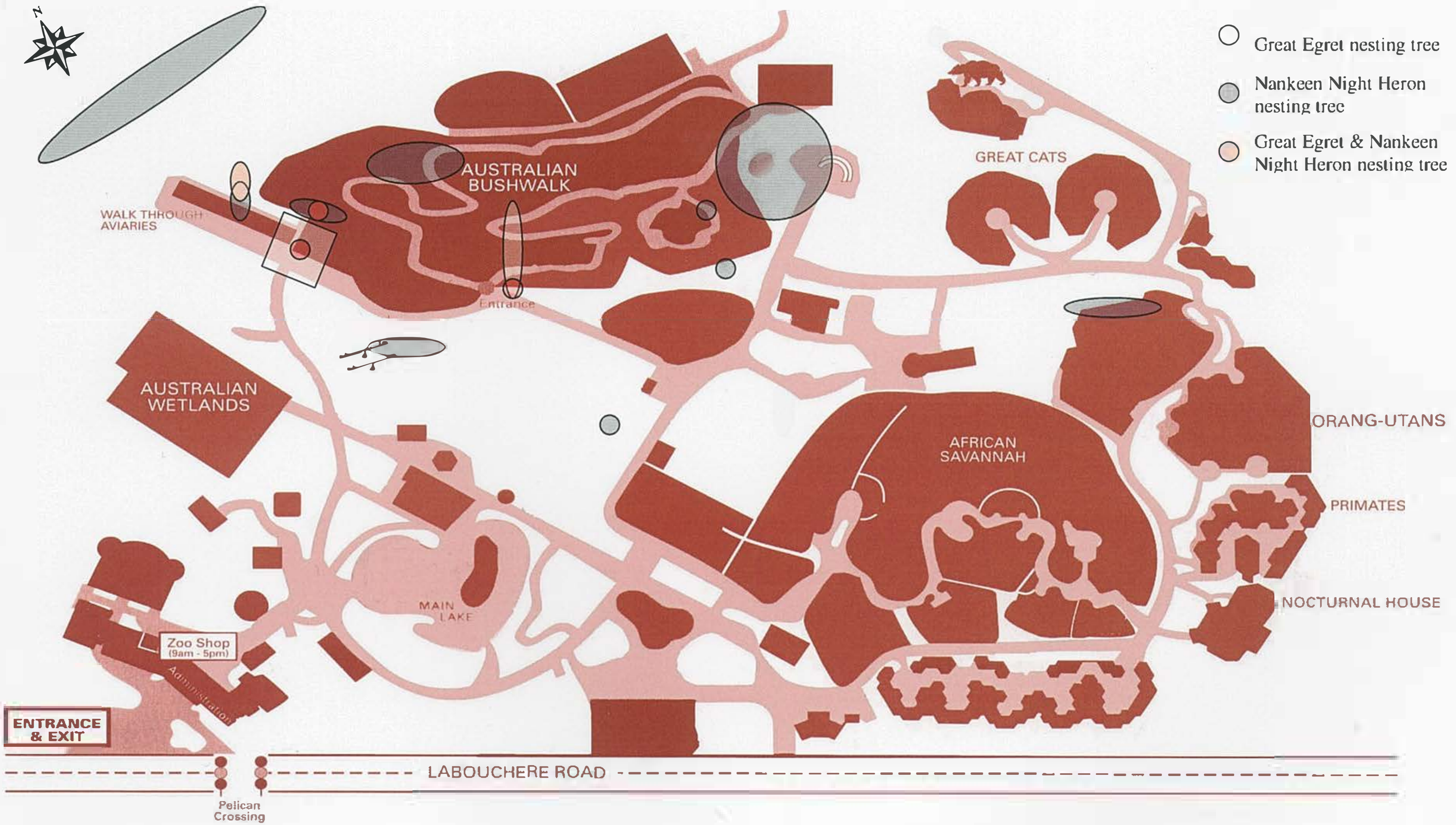

Figure 10. Map of Perth Zoo showing dispersion (shading) of Great Egret and Nankeen Night Heron nesting trees during the 1996/97 breeding season.

Map was adapted from Perth Zoological Gardens Brochure (Permission obtained by Perth Zoo for use of map).

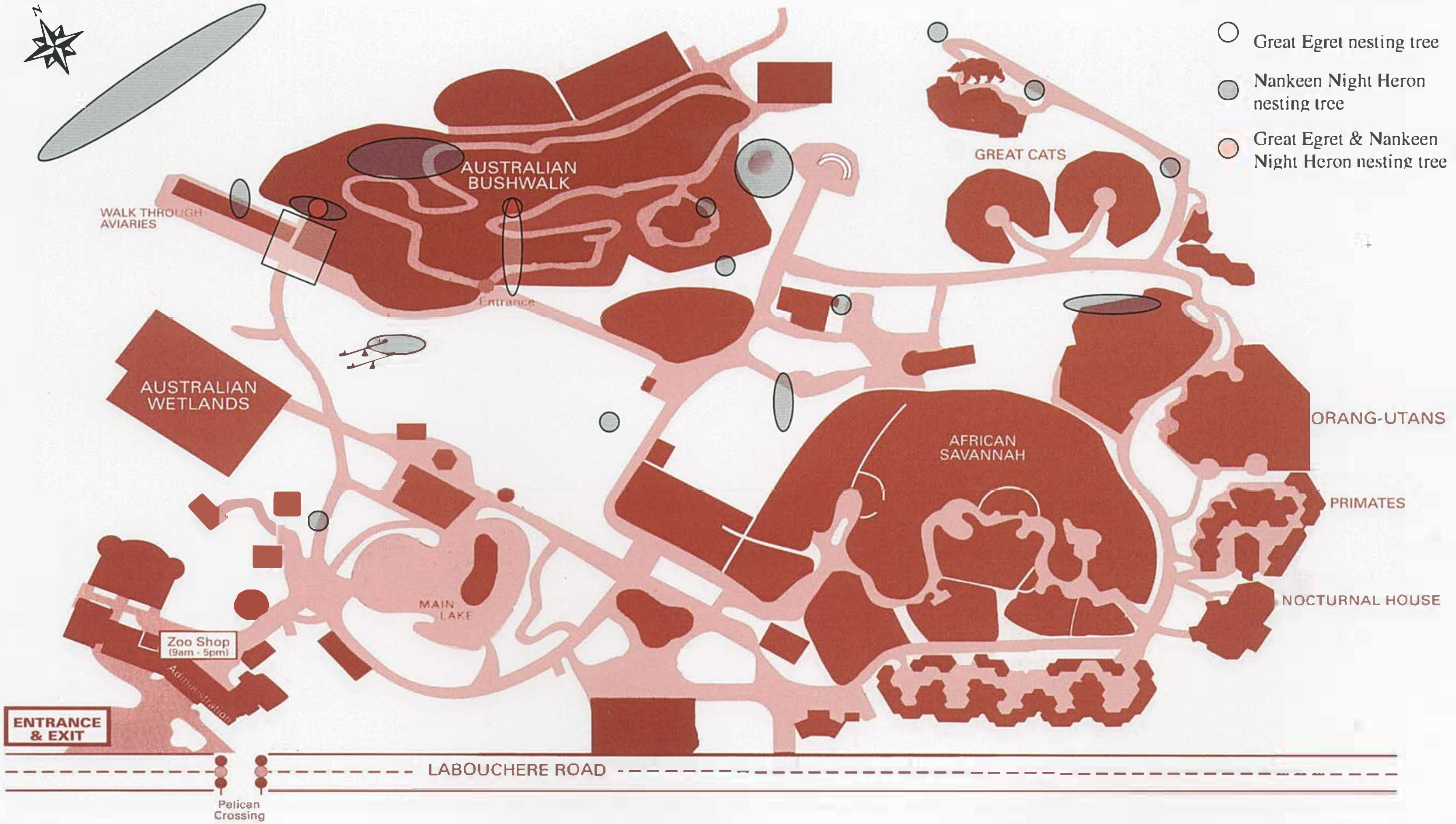

Figure 11. Map of Perth Zoo showing dispersion (shading) of Great Egret and Nankeen Night Heron nesting trees during the 1997/98 breeding season.

Map was adapted from Perth Zoological Gardens Brochure (Permission obtained by Perth Zoo for use of map).

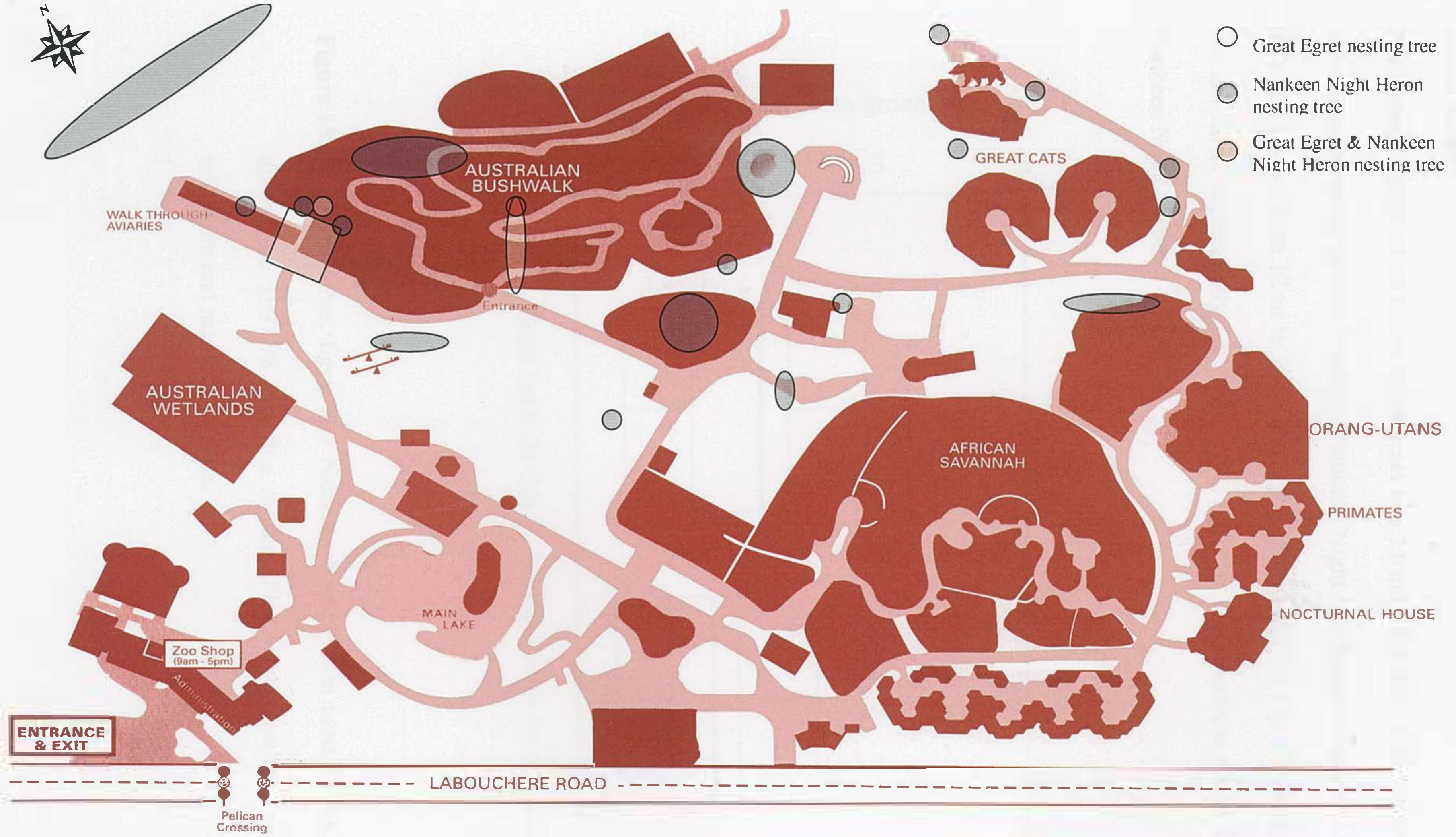

Figure 12. Map of Perth Zoo showing dispersion (shading) of Great Egret and Nankeen Night Heron nesting trees during the 1998/99 breeding season.

Map was adapted from Perth Zoological Gardens Brochure (Permission obtained by Perth Zoo for use of map).

2.3.2.2 Height

The average height of 29 Great Egret nests was 21 m (± 0.8 SE), with a range from 13 m to 29 m above the ground. Fourteen Nankeen Night Heron nests averaged 19 m (± 0.9 SE), and ranged from 12 m to 26 m above the ground (Figure 13). The height of nests did not differ significantly (df = 41, t = 1.63, p = 0.11) between Great Egrets and Nankeen Night Herons.

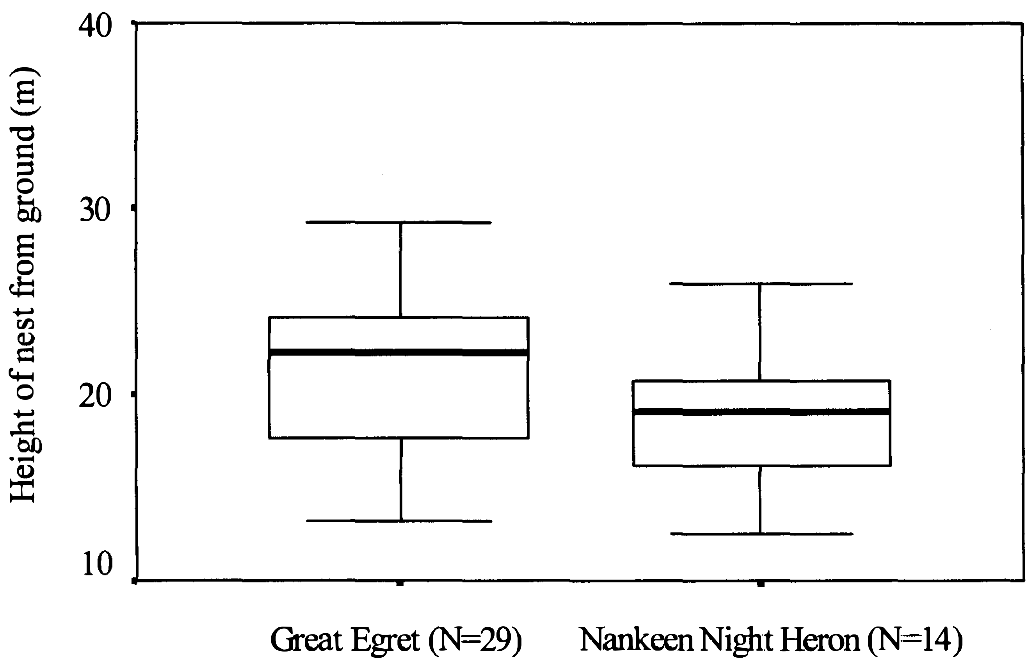

Figure 13. Height of Great Egret and Nankeen Night Heron nests in the Perth Zoo during the 1997/98 breeding season. Plot shows median, quartiles and minimum and maximum values.

2.3.2.3 Tree Species

All Great Egret nests were located in pine trees, whereas Nankeen Night Herons nested in a range of tree species including figs, pine, bamboo and eucalypt (Lemon Scented Gum, *Eucalyptus citriodora*) (Figure 14).

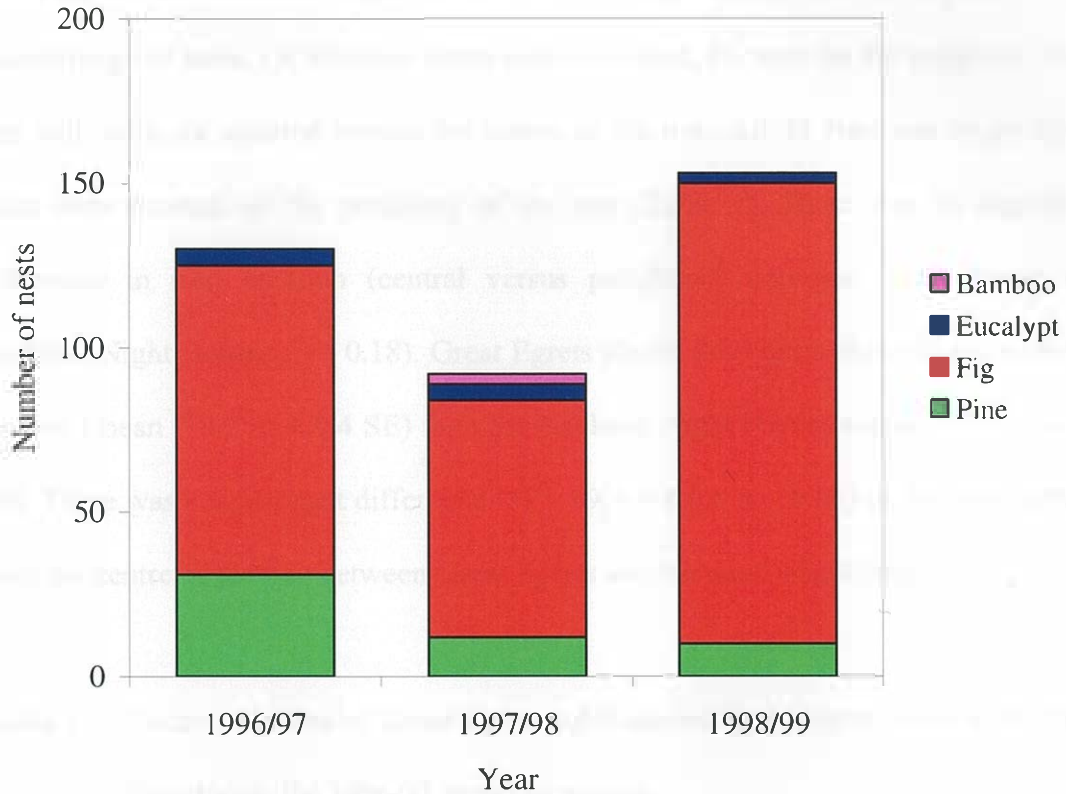

Figure 14. Nesting tree species (bar colours) of Nankeen Night Herons during the 1996/97, 1997/98 and 1998/99 breeding seasons at the Perth Zoo.

2.3.2.4 Nest Materials and Size

Great Egret and Nankeen Night Heron nests were constructed with eucalypt twigs and leaves, gathered from a range of eucalypt species in the zoo. The two Great Egret nests that were measured had a mean size of 33 (length) x 29 (width) x 10 cm (depth), and the size of the Nankeen Night Heron nest was 25 (length) x 21 (width) x 5 cm (depth) (N = 1).

2.3.2.5 Nest Location

Great Egrets and Nankeen Night Herons nested peripherally, with nests placed in the outer foliage of trees. Of 39 Great Egret nests recorded, 33 were on the periphery of the tree with only six situated toward the centre of the tree. All 14 Nankeen Night Heron nests were located on the periphery of the tree (Table 1). There was no significant difference in nest location (central versus peripheral) between Great Egrets and Nankeen Night Herons ($p = 0.18$). Great Egrets placed their nests closer to the centre of the tree (mean = 3.2 m ± 0.4 SE) than the Nankeen Night Herons (mean = 7.9 m ± 0.6 SE). There was a significant difference (df = 49, t = 6.03, $p = 0.00$) in the nest distance from the centre of the tree between Great Egrets and Nankeen Night Herons.

Table 1. Location in tree of Great Egret and Nankeen Night Heron nests in the Perth Zoo during the 1996/97 breeding season.

	Peripheral nests	**Central nests**	**Mean distance from centre of tree (m) ± SE**
Great Egret	33	6	3.2 ± 0.4
Nankeen Night Heron	14	0	7.9 ± 0.6

Overall, nests were relatively evenly distributed between aspects other than south. One Great Egret nest was located centrally on the top of the tree facing no particular direction and was not included in the analysis. Great Egrets nested less than expected in a southern direction and Nankeen Night Herons nested more than expected in a southern direction (Table 2).

Table 2. Aspect of Great Egret and Nankeen Night Heron nests located in the Perth Zoo during the 1997/98 breeding season. Figures in brackets are expected values.

	Nest Aspect			
	North	South	East	West
Great Egrets	10 (9.1)	8 (9.1)	10 (9.9)	10 (9.9)
Nankeen Night Herons	2.5 (3.9)	4.5 (3.9)	3.5 (4.1)	3.5 (4.1)

2.3.3 Reproductive Biology

Egg laying by Great Egrets commenced in September and peak nesting time, indicated by the percentage of active nests (93 to 100%), was on 9 November 1997 and 8 November 1998. Egg laying by Nankeen Night Herons commenced slightly earlier in September, and peak nesting time (72 to 79%) was on 9 November 1997 and 8 November 1998. During peak nesting time in 1997 and 1998, there were fewer Nankeen Night Heron nests active than Great Egret nests, within the selection of nests examined. Within the group of 19 pine trees selected for intensive study the number of active Great Egret nests ranged from 21 to 33 nests (N = 5 counts between years). The number of active Nankeen Night Heron nests, within the 17 fig trees selected for intensive study, ranged from 2 to 30 nests (N = 5 counts between years) (Table 3).

Table 3. Proportion of active Great Egret and Nankeen Night Heron nests (with eggs and/or chicks) in the Perth Zoo colony. Active nests were recorded in a group of 19 pine and 17 fig trees that could be observed from a cherry picker in five counts, during the 1997/98 breeding season.

Great Egrets	**Total nests counted**	**No of active nests (with eggs and/or chicks)**	**Percentage active**
9 November 1997	33	33	100
23 November 1997	31	29	94
13 December 1997	31	21	68
8 November 1998	29	27	93
22 November 1998	33	32	97
Nankeen Night Herons			
9 November 1997	32	23	72
23 November 1997	35	17	49
13 December 1997	35	2	6
8 November 1998	38	30	79
22 November 1998	34	27	79

Between year (9 November 1997 vs 8 November 1998) variation in mean number of offspring (eggs and chicks) was not significant for either Great Egrets (df = 58, t = 0.72, $p = 0.47$, N = 84, N = 72) or Nankeen Night Herons (df = 51, t = 1.31, $p = 0.20$, N = 36, N = 55). However, there was a significant difference in offspring produced between Great Egrets and Nankeen Night Herons on each of these occasions (9 November 1997: df = 54, t = 6.28, $p = 0.00$; 8 November 1998: df = 55, t = 3.99, $p = 0.00$) (Table 4).

Table 4. The number of active Great Egret and Nankeen Night Heron nests containing offspring (eggs and chicks) in the Perth Zoo colony. Eggs and chicks were recorded in a group of 19 pine and 17 fig trees that could be observed from a cherry picker in five counts, during the 1997/98 breeding season.

Date	Number of active nests containing 1 to 4 offspring				Total offspring	Mean offspring	Standard Error (±SE)
Great Egrets	1	2	3	4			
9 November 97	0	15	18	0	84	2.6	±0.09
23 November 97	2	18	9	0	65	2.2	±0.1
13 December 97	10	9	2	0	34	1.6	±0.2
8 November 98	4	2	20	1	72	2.7	±0.2
22 November 98	0	13	18	1	84	2.6	±0.1
Nankeen Night Herons							
9 November 97	12	9	2		36	1.6	±0.1
23 November 97	12	5	0		22	1.3	±0.1
13 December 97	1	1	0		3	1.5	±0.5
8 November 98	12	11	7		55	1.8	±0.1
22 November 98	8	15	4		50	1.8	±0.1

Between year (9 November 1997 vs 8 November 1998) variation in mean number of eggs was not significant for either Great Egrets (df = 39, t = 0.76, p = 0.41, N = 43, N = 56) or Nankeen Night Herons (df = 25, t = 0.19, p = 0.85, N = 19, N = 39). There was also no significant difference in eggs produced between Great Egrets and Nankeen

Night Herons on each of these occasions (9 November 1997: df = 24, t = 1.86, $p = 0.07$; 8 November 1998: df = 40, t = 0.60, $p = 0.55$) (Table 5).

Table 5. The number of active Great Egret and Nankeen Night Heron nests containing eggs in the Perth Zoo colony. Eggs were recorded in a group of 19 pine and 17 fig trees that could be observed from a cherry picker in five counts, during the 1997/98 breeding season.

Date	**Number of active nests containing 1 to 4 eggs**				**Total eggs**	**Mean eggs**	**Standard Error (±SE)**
Great Egrets	1	2	3	4			
9 November 97	0	8	9	0	43	2.5	±0.1
23 November 97	1	6	0	0	13	1.9	±0.1
13 December 97	1	1	0	0	3	1.5	±0.5
8 November 98	7	3	13	1	56	2.3	±0.2
22 November 98	2	6	9	1	45	2.5	±0.2
Nankeen Night Herons							
9 November 97	1	6	2	0	19	2.1	±0.2
23 November 97	1	1	0	0	3	1.5	±0.5
13 December 97	0	0	0	0	0	-	-
8 November 98	4	7	7	0	39	2.2	±0.2
22 November 98	3	12	3	0	19	2.1	±0.2

Between year (9 November 1997 vs 8 November 1998) variation in mean number of chicks was significant for Great Egrets (df = 22, t = 2.51, $p = 0.02$, N = 41, N = 15), but not significant for Nankeen Night Herons (df = 24, t = 0.66, p = 0.52, N = 17, N = 16). Variation in mean number of chicks between Great Egrets and Nankeen Night Herons was significant on 9 November 1997 (df = 28, t = 7.77, p = 0.00) but not significant on 8 November 1998 (df = 18, t = 1.83, p = 0.08) (Table 6).

Table 6. The number of active Great Egret and Nankeen Night Heron nests containing chicks in the Perth Zoo colony. Chicks were recorded in a group of 19 pine and 17 fig trees that could be observed from a cherry picker in five counts, during the 1997/98 breeding season.

Date	**Number of active nests containing 1 to 3 chicks**			**Total chicks**	**Mean chicks**	**Standard Error (±SE)**
Great Egrets	1	2	3			
9 November 97	0	7	9	41	2.6	±0.1
23 November 97	4	12	8	52	2.2	±0.1
13 December 97	9	8	2	31	1.6	±0.2
8 November 98	3	3	2	15	1.9	±0.3
22 November 98	0	9	7	39	2.4	±0.1
Nankeen Night Herons						
9 November 97	11	3	0	17	1.2	±0.1
23 November 97	11	4	0	19	1.3	±0.1
13 December 97	1	1	0	3	1.5	±0.5
8 November 98	8	4	0	16	1.3	±0.1
22 November 98	8	3	0	14	1.3	±0.1

2.3.3.1 Mortality

Between October 1997 and January 1998, 38 Great Egret chicks and 2 eggs, and 12 Nankeen Night Heron chicks and 3 eggs, were found dead at the base of nesting trees, in nests, and wedged in trees (Figure 15). There was no significant difference in the number of dead found between Great Egrets and Nankeen Night Herons (df = 53, t = 1.74, p = 0.2). In the 1998/99 breeding season, 6 Great Egret chicks and 5 Nankeen Night Heron chicks were found dead. The greater number of Nankeen Night Heron offspring found dead early in the season is probably due to their commencing nesting earlier. Nine Great Egret chicks were lost over the two breeding seasons as a result of using the cherry picker for counting, but these were not considered natural mortalities.

No correlation was found between the number of dead Great Egret offspring found during the 1997/98 breeding season, and daily temperature (r = 0.029; p = 0.890) and rainfall (r = -0.233; p = 0.263). No correlation was also found between the number of dead Nankeen Night Heron offspring found during the 1997/98 breeding season, and temperature (r = 0.356; p = 0.347) and rainfall (r = 0.225; p = 0.561).

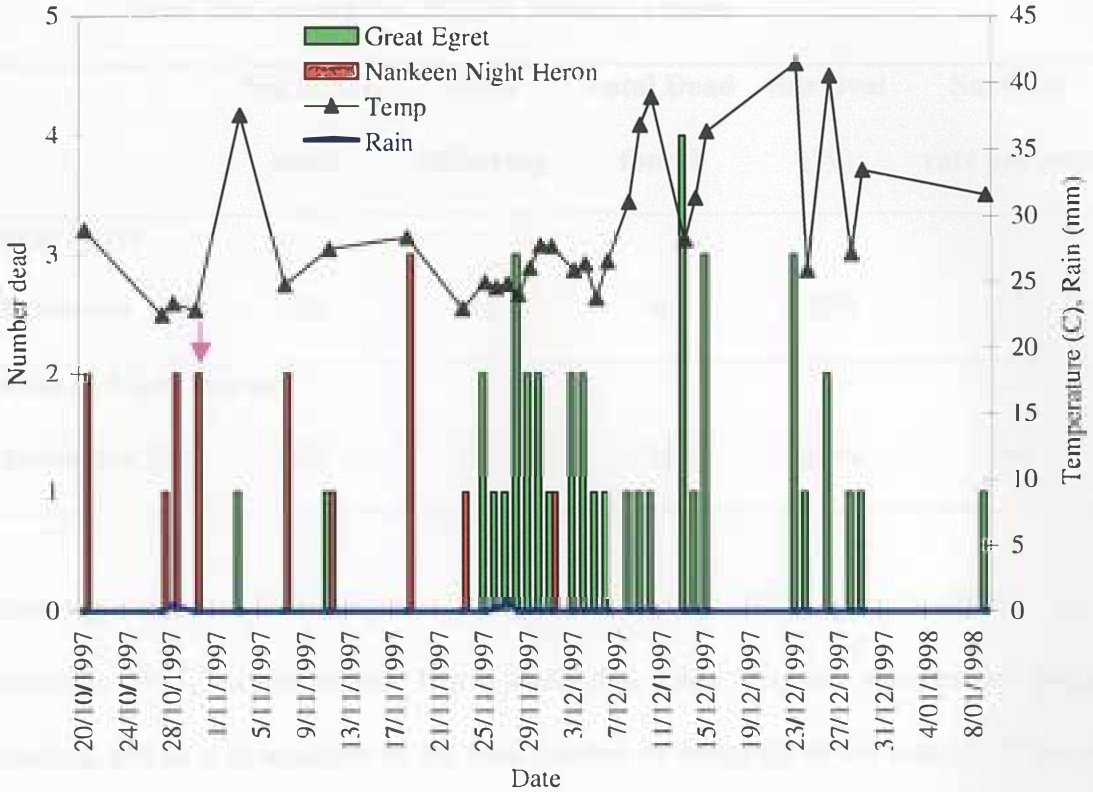

Figure 15. Number of dead Great Egret (red bars) and Nankeen Night Heron (green bars) chicks and eggs found at the Perth Zoo, with maximum daily temperature (degrees Celsius) and rainfall (millimetres), during the 1997/98 breeding season. Pink arrow represents a storm on 30 October 1997.

2.3.3.2 Survival Rate

Eighty four Great Egret and 36 Nankeen Night Heron offspring (eggs and chicks) were counted from the cherry picker on 9 November 1997. Great Egret offspring were counted in all visible nests in 19 pines and Nankeen Night Herons offspring were counted in 17 fig trees (Table 7).

Table 7. Minimum survival rate for Great Egrets and Nankeen Night Herons in the Perth Zoo, during the 1997/98 breeding season.

	No. active nests	Total Offspring	Total Dead found	Survival (%)	Survival rate per nest
Great Egret					
9 November 1997	33	84	40	52%	1.3
Nankeen Night Heron					
9 November 1997	23	36	15	58%	0.9

Most eggs laid by Great Egrets (95%) and Nankeen Night Herons (89%), on 9 November 1997, became chicks. It was likely that many offspring were missed during counting, and so a comparison of the total number of offspring to the number of known deaths suggests a minimum survival rate of 52% (1.3 offspring per nest) for Great Egrets and 58% (0.9 offspring per nest) for Nankeen Night Herons. The percentage survival was higher for Nankeen Night Herons as there was a higher offspring to dead ratio. The survival rate per nest was higher for Great Egrets as the ratio of surviving offspring to active nests was greater.

2.3.4 Departure Patterns

A total of 86 observations were made of Great Egrets departing from the zoo colony (Figure 16). In the two minutes following the initial Great Egret departures, 31 departures then occurred. Of these 31 departures, 19 (61%) were in the same direction as the initial departing bird, and 12 (39%) were not. The number of Great Egrets departing initially and following ranged from one to seven birds.

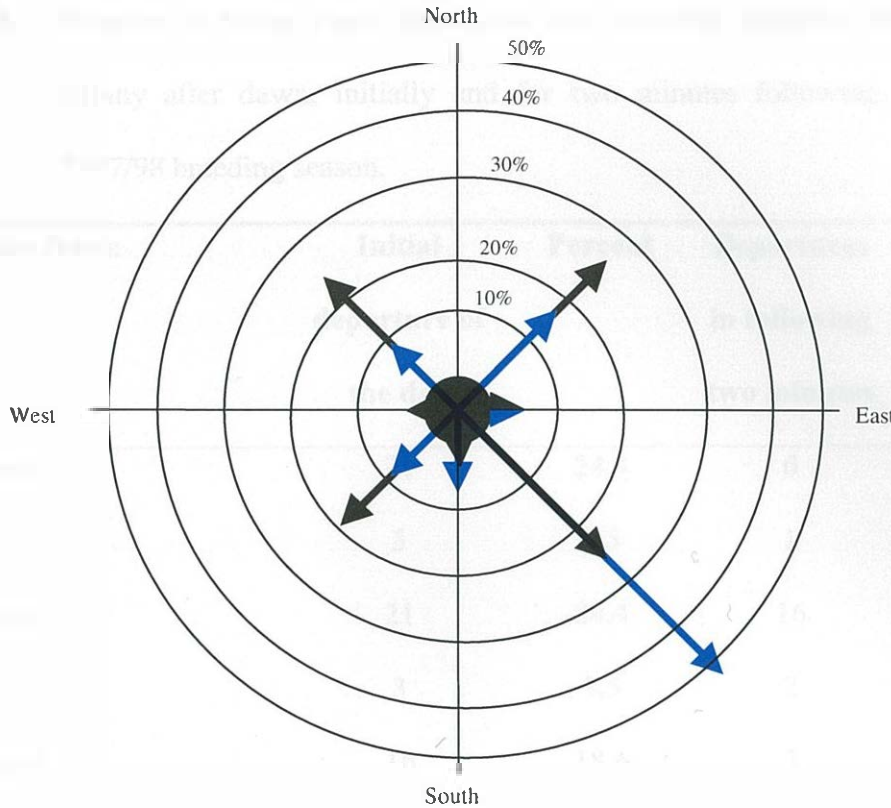

Figure 16. Percentage of departure directions of Great Egrets initially (black arrow) and in the following two minutes (blue arrow) at Perth Zoo, during the 1997/98 breeding season.

Of the initial Great Egret departures, 21 (24%) were in a northern direction, 21.5 (25%) in a southern direction, 24 (28%) in an eastern direction and 19.5 (23%) departed in a western direction. Of the following Great Egret departures within the two minutes, 4.5 (14%) were in a northern direction, 11.5 (37%) in a southern direction, 12 (39%) in a eastern direction and 3 (10%) departed in a western direction (Table 8). There was no significant difference (χ^2 = 5.001, df = 3, P = 0.17) in the direction of departure between the initial and following Great Egrets.

Table 8. Number of Great Egret departures and direction departed from the zoo colony after dawn, initially and for two minutes following, during the 1997/98 breeding season.

Direction flown	Initial departure of the day	Percent	Departures in following two minutes	Percent
Northeast	21	24.4	6	19.3
East	3	3.5	1	3.2
Southeast	21	24.4	16	51.6
South	3	3.5	2	6.5
Southwest	16	18.6	3	9.7
West	1	1.2	0	
Northwest	21	24.4	3	9.7

2.3.5 Banding

A total of 14 Great Egret chicks, including seven during the 1997/98 breeding season, and seven during the 1998/99 breeding season, were banded after falling from their nests. Thirteen of these birds were released within the zoo grounds and one at Joondalup Lake. A request was placed in 1997 in the Birds Australia newsletter for the public to report sightings of banded egrets and herons, but none has been received. Nankeen Night Heron chicks rarely fell from their nest and survived, and therefore none was banded.

2.4 Discussion

2.4.1 Perth Zoo Colony

The Perth Zoo colony of Great Egrets and Nankeen Night Herons consists of over 170 breeding pairs (130 Nankeen Night Heron and 49 Great Egret pairs), and represents a significant presence of Great Egrets and Nankeen Night Herons in the Perth Metropolitan area. The colony is sizeable in comparison to other Great Egret colonies in the southwest, which can range from a few to 120 breeding pairs (Johnstone & Storr 1998). Nankeen Night Heron colonies are scattered throughout the southwest, but can range up to 3000 breeding pairs (Marchant & Higgins 1990). Previous counts of the number of Great Egrets breeding at the Perth Zoo were undertaken by the Royal Australasian Ornithologists Union (RAOU), from 1986 to 1988. Ten Great Egret nests were counted in 1986/87, five in 1987/88, and 20 in 1988/89. Nankeen Night Heron nests were not counted (Jaensch & Vervest 1989). Extraneous factors, including different counting methods, may have contributed to the greater number of Great Egret nests counted in this study.

There was an increase in the number of Nankeen Night Herons nesting at the Perth Zoo from 1996 to 1998, although the number of Great Egret nests declined. The removal of two Great Egret nesting trees in 1997 for exhibition expansion may have contributed to this decline. Burkholder and Smith (1991) found that a decline in the colony size of Great Blue Herons was related to a decrease in the number of available trees. Variation in yearly colony size may be normal in the long term. Tourenq *et al.* (2000), in a study of the long term population trends of Cattle Egrets, Little Egrets, Black-crowned Night Herons and Squacco Herons (*Ardeola ralloides*) in South France, found that the number of nests in the colony varied extensively, sometimes by up to a few hundred, according to local and external environmental factors and individual life history characteristics.

There appeared to be a general trend between Great Egret nesting attempts and annual rainfall, where as annual rainfall declined, so did the nesting attempts of the Great Egret. However, given the limited data this result should be treated with caution. Jaensch and Vervest (1989), in a study of Great Egret colonies in the southwest of Western Australia, found that the total number of Great Egret breeding pairs in an area was lower in years of low rainfall than in wetter years.

2.4.2 Nest Site Selection

In Australia, Great Egrets and Nankeen Night Herons have been recorded nesting in a variety of native tree species (Marchant & Higgins 1990). Although similar native tree species were available at Perth Zoo, Great Egrets and Nankeen Night Herons selected tall pine and fig trees respectively. These species provided dense, sheltering and supporting vegetation. The association between vertical alignment of birds through nesting vegetation and body size, as suggested by Burger (1979), and Fasola and Alieri (1992), was not evident in this study. As both bird species nested in tall trees, it was likely that some other factor beside body or nest size determined nest height. Burger and Gochfeld (1990) found that vertical nest stratification in a herony in Madagascar reflected the scarcity of trees and aggressiveness of one of the species, rather than body size. Burger (1979) and Krebs (1974) also suggest that tall trees provide some protection against predators, and Ranglack *et al.* (1991) suggest that nests placed higher up in a tree are usually constructed in more stable vegetation. Gibbs and Kinkel (1997) also suggest that herons may nest in a variety of vegetation types as long as protection from disturbance by predators and humans are met. As many people visit the Perth Zoo daily, it is highly likely that nesting in tall trees by Great Egrets and Nankeen Night Herons is related to avoiding human disturbance, rather than to body size, scarcity of trees, predation or unstable vegetation.

Great Egrets are known to place their nests on the top and periphery of trees (Marchant & Higgins 1990), which was also found in this study. Post (1990) states that variations in horizontal nest placement may be based on nest size. As the Great Egret is a large bird, which builds a large nest (Johnstone & Storr 1998), an accessible and stable platform towards the exterior of a tree is required, particularly when taking off and landing. Nests that are built on branches too far from the centre of the tree however, may be too unstable for a larger bird such as the Great Egret. This is probably why the Nankeen Night Heron, a smaller bird with a smaller nest (Johnstone & Storr 1998), was slightly more flexible in positioning its nest in a tree and was able to nest further out on the branches than the Great Egret.

Excluding nest height, there was little evidence to suggest that nest placement affects the breeding success of egrets and herons (Baxter 1994a; Kazantzidis *et al.* 1997; Ranglack *et al.* 1991). Although it was not possible to compare aspect with breeding success, in the Perth Zoo colony Nankeen Night Herons faced their nests more than expected in a southerly direction. Great Egrets on the other hand, faced their nests less than expected in a southerly direction. Departure directions of the Great Egret were mostly in northern, eastern and western directions, which would be expected if more nests were faced in these directions.

2.4.3 Reproduction

The breeding season of the Great Egret and the Nankeen Night Heron colony at the Perth Zoo is similar to that recorded for both species from the southwest of Western Australia in general. Johnstone and Storr (1998) and Storr (1991) recorded Great Egrets laying eggs from September to November, and Nankeen Night Herons laying eggs from September to December. Although in this study, observations of both species were only made for part of the year, Nankeen Night Herons have previously been recorded as breeding all year round (Spence 1981). Great Egrets and Nankeen Night Herons generally bred in synchrony, with the exception of some early and late additions to the colony. Synchronised breeding appears to be common in heron and egret colonies (Baxter 1994a; Krebs 1978).

The clutch size of the Great Egret was slightly larger (mean = 2.6 to 2.7; range = 1 to 4) than the Nankeen Night Heron (mean = 1.6 to 1.8; range = 1 to 3), which also coincided with a slightly higher mortality rate. The clutch size recorded for both species is somewhat lower than that reported elsewhere. Hancock and Kushlan (1984) reported a clutch size for Great Egrets of two to five and two to three for Nankeen Night Herons. In Italy, Fasola and Pettiti (1993) recorded a clutch size of three to four for the Black-crowned Night Heron, a similar species to the Nankeen Night Heron. Marchant and Higgins (1990) reported a clutch size for the Great Egret and Nankeen Night Heron in Australia of three to four. In Western Australia, Johnstone and Storr (1998) reported a clutch size of three to four for Great Egrets and two to four for Nankeen Night Herons. Ranglack *et al.* (1991) recorded variations in clutch size in Cattle Egrets and suggested they may occur as a result of differences in study methods. In some studies, reproductive data on herons and egrets are obtained by marking nests and eggs (Erwin *et al.* 1996; Fasola & Pettiti 1993; Frederick *et al.* 1992; Inoue 1985; Kazantzidis *et al.* 1997; Ranglack *et al.* 1991). In this study this was not possible. The clutch size of the Great Egret and Nankeen Night Heron were minimum estimates and therefore were expected to be slightly lower than those reported from other studies.

Food availability may have influenced clutch size of the Great Egret and the Nankeen Night Heron in this study. Fasola and Pettiti (1993) found that local food abundance may limit clutch size. Powell (1983) found that Great Blue Herons with supplemented diets had an average clutch size of 3.5, compared with 2.9 with an unsupplemented diet. Other factors, such as environmental fluctuations and predation, also may directly impact on the number of young.

2.4.3.1 Mortality

A major cause of chick mortality, as reported by Butler (1997) and Ranglack *et al.* (1991), is the inability of chicks to return to their nest after falling out. This appeared to be the main cause of Great Egret chick mortality observed at the Perth Zoo, where chicks that strayed too far from their nest were often unable to return. Siblicide, or sibling aggression, as discussed by Mock *et al.* (1987), may also influence chick mortality. However, it was not possible to measure this in the Perth Zoo colony. Predation of chicks at the zoo colony was also not observed during this study, but Spence (1981) recorded Nankeen Night Herons preying on Great Egret offspring in the Perth Zoo colony.

The persistence of the Great Egret and Nankeen Night Heron colony at the Perth Zoo colony over many years suggests that the continual presence of humans within the zoo grounds has little impact on the mortality rate of the Great Egret and Nankeen Night Heron. Butler (1997) noted the location of a Great Blue Heron colony within a zoo had little effect on breeding. These results support Vos's *et al.* (1985) conclusion that herons may habituate to repeated, non-threatening activities. The Great Egrets' and Nankeen Night Herons' habit of nesting in tall trees also enabled them to minimise any potential disturbances from humans below. The only human disturbance known to result in mortalities was from the researchers (Phillimore & Recher 1999; Appended).

Weather conditions (rainfall and temperature) appeared to have little effect on the mortality rate of Great Egrets and Nankeen Night Herons during this study. Environmental factors have been known however, to affect egret and heron survival (Bancroft *et al.* 1988; Baxter 1994a; Maddock & Baxter 1991). Increases in mortality have been observed following long periods of high temperatures and drought (Maddock & Baxter 1991) and extreme weather events, such as hurricanes (Shepherd *et al.* 1991). A small increase in Nankeen Night Heron chick mortality at the Perth Zoo was observed following a storm in 1997. It is probable, however, that data collected over a longer period of time may be required to elucidate the relationship between weather and mortality.

Chick mortality was slightly higher for Great Egrets than for Nankeen Night Herons and this was possibly a result of increased brood size. Mock and Parker (1986) found that mortality of Great Egrets in particular, was brood-size dependent where, as brood size decreased, survivorship increased. Great Egrets in this study had larger broods than the Nankeen Night Herons.

2.4.3.2 Survival Rate

The survival rate per nest for Great Egrets (1.3) was higher than that for the Nankeen Night Heron (0.9). Great Egrets maintain a greater overall survivorship by producing larger clutches initially, despite a higher mortality rate and subsequent decrease in brood size.

The survival rate for both the Great Egret and the Nankeen Night Heron at the Perth Zoo colony was average to low, in comparison with other studies. The Black-crowned Night Heron was recorded by Fasola and Pettiti (1993) in Italy, and Kazantzidis *et al.* (1997) in Greece as having a survival rate per nest of around 2.5. Pratt and Winkler (1985) recorded a survival rate in California between 0.03 and 2.0 for the Great Egret, Marchant and Higgins (1990) reported a survival rate in Shortland (New South Wales) ranging from 1.8 to 2.4 and Maddock and Baxter (1991) recorded a survival rate in New South Wales ranging from 1.8 to 2.5. A smaller clutch size in this study may have contributed to the difference. The survival rate recorded in this study was only for one year and was a minimum estimate, and may not be representative of the overall colony success. Butler *et al.* (1995) found that the number of Great Blue Heron nesting pairs in colonies and fledging success was highly variable between years, and therefore studies that last only a few years and include low numbers of colonies might not be representative of overall fledging success within those colonies or regions. Although clutch size and survival rate were average to low compared to other studies, the persistence of the colony for over 25 years suggests it is viable.

A number of environmental factors such as weather, predation and disturbance may have influenced the mortality rate and hence survival rate at the zoo colony. The effect of rainfall and subsequent food availability on wading bird nesting success or chick survival has been widely reported (Bancroft *et al.* 1988; Jaensch & Vervest 1989; Powell 1983; Mock *et al.* 1987). Maddock and Baxter (1991), in a study on the effect of rainfall on egret breeding success in Shortland, New South Wales, found that aquatic feeders such as the Great and Little Egrets were less successful during dry seasons when food availability was low. Mock and Parker (1986) found that food abundance was the limiting factor in the survivorship of Great Egret broods. Unfortunately survivorship could not be compared with rainfall in this study. As Nankeen Night Herons supplemented their diets with food found within the zoo grounds, they may not be as susceptible to food shortages within the metropolitan area.

2.4.4 Information Sharing

The direction of departure between the initial and following Great Egrets was not significantly different, suggesting that some information may have been exchanged within the colony. Information exchange would benefit Great Egrets foraging in the Perth Metropolitan area as many wetlands dry out over summer (Storey *et al.* 1993), leaving small temporary pools of water containing concentrated prey. Providing the leading bird has knowledge of such pools, following other Great Egrets from the colony would enable more birds to access these pools with minimal search effort.

Custer and Osborn (1978b) note that no study has yet been able to produce direct evidence that demonstrates unsuccessful birds following successful birds to feeding grounds. This study also does not provide direct evidence for the 'information sharing' hypothesis. It is possible, however, that some information may be exchanged within the colony as nearly two out of three departures occurred in the same direction as the leading Great Egret. An alternative explanation would be it was coincidental that the departures were in the same direction. Erwin's (1983) comments that local conditions, such as water level, play a greater part than information sharing still holds some merit, but may not be the only deciding factor for the initial departure of the day from the colony.

2.4.5 Offspring Re-sightings

Banded Great Egret chicks from the Perth Zoo were not re-sighted or recaptured during the course of this study, therefore no conclusion could be made in regards to their survival rate and the practicality of rehabilitating Great Egret chicks. Generally, Great Egret chicks are known to have a high mortality rate in the first year of their life. Kahl (1963) recorded a mortality of 76% in the first year, compared to 26% per year following.

No banded Great Egrets from the Perth Zoo were re-sighted, therefore it was not possible to determine their dispersion pattern. Studies of banded Great Egrets in the southwest of Western Australia indicate that juveniles are able to move long distances after fledging, travelling 191 km after only two months of fledging (Geering *et al.* 1998). Adult Great Egrets may travel even longer distances, for example, Geering *et al.* (1998) recorded a Great Egret travelling over 3000 km to New Guinea. Geering *et al.* (1998) suggest that egrets from coastal areas, where there is less climatic variation, move shorter distances than egrets from inland areas where severe droughts have a greater impact. Therefore, egrets from the zoo colony may move towards small wetlands short distances inland and south. Further banding of Great Egret chicks from the zoo is required to investigate their movements.

2.5 Conclusion

The number of Nankeen Night Herons nesting at the Perth Zoo from 1996 to 1998, increased from 130 to 153 nests, while the number of Great Egret nests declined from 49 to 36. The removal of two Great Egret nesting trees in 1997 for exhibition expansion may have contributed to this decline. There was a general trend between annual rainfall and the number of Great Egret nests counted in the Perth Zoo from 1996 to 1998. Great Egrets were specific in their choice of nesting tree species, while Nankeen Night Herons were less specific. Horizontal nest placement appeared to be related to body size. Both species selected tall trees that provided dense, sheltering and supporting vegetation, away from on-ground disturbances. Great Egrets placed their nests near the top and periphery of trees, while Nankeen Night Herons nested even further out on the branches due to their smaller body size. Great Egrets faced their nests less often in a southerly direction, and Nankeen Night Herons faced their nests more often in a southern direction. The breeding season of the Great Egret and Nankeen Night Heron was similar to other records for both species from the southwest of Western Australia. Their clutch size, however, was slightly lower than reported, possibly because of differences in study methods. Chick mortality was slightly higher for Great Egrets than for Nankeen Night Herons, maybe a result of larger broods (Mock & Parker 1986). Most chick deaths observed resulted from their inability to return to their nest after falling out. Weather conditions, including rainfall and temperature, appeared to have little effect on the mortality rate of either species. There was some evidence that Great Egrets used colonies as information centres where information was gathered about productive feeding grounds. The overall survival rate per nest for Great Egrets and Nankeen Night Herons at the Perth Zoo colony was average to low, in comparison to other studies.

Nevertheless, the existence of the colony for more than 25 years suggests that it is viable. Lack of local resources caused by low rainfall in the Perth Metropolitan area may be a limiting factor for nesting Great Egrets.

Chapter 3 Foraging Ecology

3.1 Introduction

Egrets, and wading birds in general, are often regarded as biological indicators of the health of wetlands (Custer & Osborn 1977; Kushlan 1993). Therefore, it is important to understand the habitat requirements of breeding and non-breeding populations (Post 1990). In particular, the distribution, extent and quality of available feeding areas are related to reproductive success, distribution of colony sites, and the size of heron colonies (Bancroft *et al.* 1988; Butler 1997; Gibbs & Kinkel 1997; Kelly *et al.* 1993; Naugle *et al.* 1996).

The foraging behaviour of egrets has been well studied in America (Kushlan 1976; Kushlan 1978a; Recher & Recher 1980; Rodgers 1983; Willard 1977), Africa (Whitfield & Blaber 1979) and Europe (Dimalexis *et al.* 1997; Fasola 1986). In Australia, studies are restricted to the Northern Territory, New South Wales and the Great Barrier Reef. Recher and Holmes (1982) described the foraging behaviour of Little Egrets, Pied Herons (*Ardea picata*), Great Egrets, Intermediate Egrets and White-necked Herons (*Ardea pacifica*), and found that as most species feed on fish and/or frogs, they were at risk from contamination of the aquatic environment. Recher *et al.* (1983) described the foraging behaviour of seven species of egrets and herons in the Northern Territory and the Hawkesbury River (New South Wales). They found Australian herons used the same foraging methods as the North American herons and species differed by size, time of foraging and habitat. Recher and Recher (1980) described the foraging behaviour of the Eastern Reef Egret, on the Great Barrier Reef, as a pursuer which spent long periods chasing smaller sized prey. No studies have yet been undertaken on the foraging ecology of egrets in Perth wetlands.

The southwest of Western Australia has a typically Mediterranean type climate, with warm to hot, dry summers and mild, wet winters (Bushplan 1998). Inland aquatic habitats are limited and vary significantly in extent each year (Lane *et al.* 1996; Jaensch & Vervest 1989). Ardeids that forage in aquatic habitats are particularly vulnerable to food shortages caused by the drying of wetlands. In New South Wales, Maddock and Baxter (1991) found that egrets feeding in aquatic habitats were vulnerable to food shortages caused by dry weather and desiccation. Variable rainfall and its timing affects the chances of successful nesting by influencing the availability of food near colony sites (Bancroft *et al.* 1988). In particular, Maddock and Baxter (1991) found the breeding success of Great, Little and Intermediate Egrets (aquatic feeders) the most adversely affected, compared with Cattle Egrets (terrestrial feeders).

This chapter describes the foraging behaviour of the Great Egret. It was not possible to observe Nankeen Night Herons as they forage mostly at night. Therefore another species occasional to wetlands, the Little Egret, was observed for comparison with the Great Egret. Differences between the foraging behaviour of the two egret species were compared to highlight specific adaptations in their hunting strategies and diet. These included foraging methods, prey type and size captured, habitat type, cloud cover, wind direction and speed, and water depth. Food taken within the zoo by the Great Egret and Nankeen Night Heron was also recorded. Kushlan's (1978a) and Recher's *et al.* (1983) studies on egrets from North America and Australia were used as a basis for describing and comparing the foraging repertoire of the Great Egret in the Perth Metropolitan area.

This study provides baseline foraging behaviour data that can be used for the management and conservation of the Great Egret and Little Egret. Specific hypotheses addressed were:

- The foraging behaviour of Great Egrets and Little Egrets in Perth Metropolitan wetlands is the same as described elsewhere in the world.
- Foraging activity is correlated with bird size where larger birds show less foraging behaviours than smaller birds.
- Great Egrets feed on fish, Little Egrets feed on a range of prey types.
- Great Egrets feed on larger prey than Little Egrets as a result of their larger body size.
- Habitat type, cloud cover, wind speed and direction and water depth affect the foraging success of Great Egrets and Little Egrets.
- Great Egrets forage in deeper water than Little Egrets due to their larger body size.

3.2 Methods

3.2.1 Study Sites

Foraging behaviour of Great Egrets and Little Egrets was documented from September 1996 to March 1997 at numerous wetlands within the Perth Metropolitan area (Figure 17).

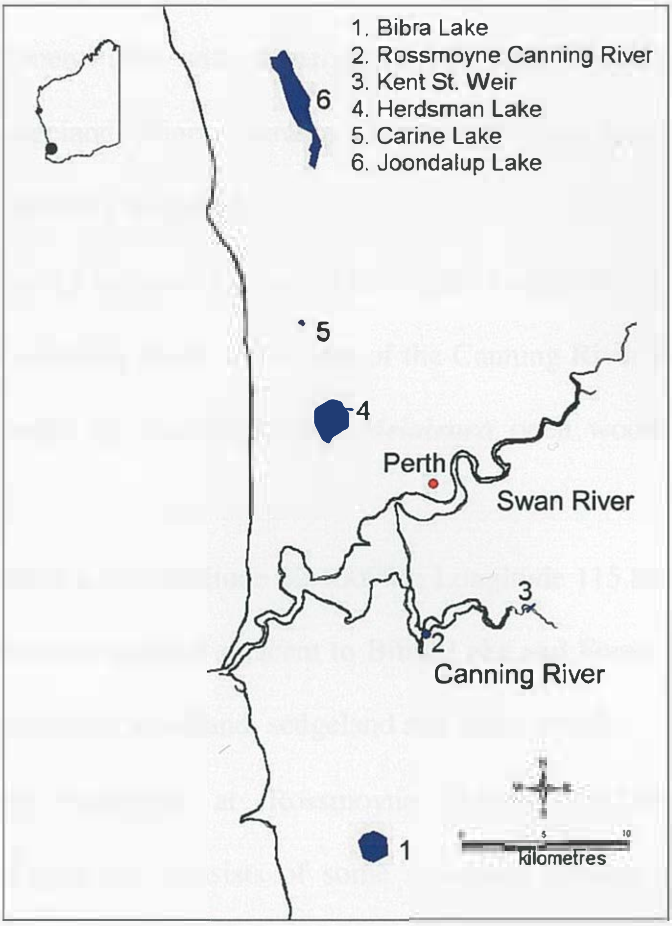

Figure 17. Map of Perth Metropolitan area showing study wetland sites (blue) and Perth city (red point).

Both bird species are common at a number of wetlands with observations undertaken at six sites:

- Joondalup Lake (550 hectares; Latitude 31.76096S; Longitude 115.78676E) (Figure 18) is part of the Yellagonga Regional Park and consists of *Eucalyptus* and *Banksia* woodland, with tall sedgeland areas alongside a permanent wetland.
- Carine Lake (20 hectares; Latitude 31.85208S; Longitude 115.78258E) (Figure 19) is a permanent swamp with upland areas consisting of open *Eucalyptus* woodland, surrounding low closed *Melaleuca* forest and sedgeland.

- Herdsman Lake (250 hectares; Latitude 31.90937S; Longitude 115.80207E) (Figure 20) is a permanent lake with *Eucalyptus rudis* and *Melaleuca* sp. woodland surrounding sedgeland. Ninety percent of the vegetation present at this lake is degraded to completely degraded.
- Kent Street Weir (1 hectare; Latitude 32.02120S; Longitude 115.92114E) (Figure 21) crosses the Canning River and is part of the Canning River Regional Park. The river is surrounded by *Eucalyptus* and *Melaleuca* open woodland, fringed with sedgelands.
- Subsidiary of Bibra Lake (Latitude 32.10090S; Longitude 115.82014E) (Figure 22), temporary freshwater wetland adjacent to Bibra Lake and Forest Road's containing *Banksia* and *Melaleuca* woodland, sedgeland and many weeds.
- Canning River Foreshore at Rossmoyne (Latitude 32.03776S; Longitude 115.86119E) (Figure 23) consists of some woodland species but mostly cleared areas with some sedges (Bushplan 1998; Storey *et al.* 1993).

Figure 18. Lake Joondalup (northern side of Ocean Reef Road) (Latitude 31.76096S; Longitude 115.78676E).

Figure 19. Carine Lake (Latitude 31.85208S; Longitude 115.78258E).

Figure 20. Herdsman Lake (Latitude 31.90937S; Longitude 115.80207E).

Figure 21. Kent Street Weir (Latitude 32.02120S; Longitude 115.92114E).

Figure 22. Subsidiary of Bibra Lake (Latitude 32.10090S; Longitude 115.82014E), adjacent to Bibra Lake and Forest Roads.

Figure 23. Canning River Foreshore at Rossmoyne (Latitude 32.03776S; Longitude 115.86119E).

3.2.2 Foraging

The foraging behaviour can be described as those postures and actions directed at obtaining prey (Kushlan 1978a). Kushlan (1978a) and Recher *et al.* (1983) described 24 foraging behaviours for the Great Egret, and Recher *et al.* (1983) described 13 behaviours for the Little Egret. Their terminology was used to describe the foraging behaviour in this study. Foraging Great Egrets and Little Egrets were observed from February to December in 1996 and February to mid April in 1997, at wetlands within the Perth Metropolitan area. For Great Egrets, 310 foraging observations were made, and for Little Egrets, 39 foraging observations were made. Observations were made during daylight hours using 10 x 40 binoculars, for 60 seconds at a time, with a maximum of 70 minutes of observation on any individual. Where large numbers of birds were present, each bird was observed in sequence. When only one bird was present, it was observed until another arrived. In addition to behaviours, a number of other foraging characteristics were recorded. During each 60 second period, the number of successful strikes (those strikes or stabs that resulted in the capture of prey) and unsuccessful strikes (those strikes or stabs that did not result in the capture of prey) were recorded. The number of steps taken during 60 seconds was tallied using a counter. An additional timer was used to record the time birds spent moving. The time spent standing still was calculated by deducting the time spent moving from the total observation time. If the bird being observed ceased feeding for more than 60 seconds, another bird was selected (Dimalexis *et al.* 1997; Recher *et al.* 1983).

The type and size of captured prey were recorded and, where possible, identified to species. Prey that could not be clearly seen was not included in the final analyses. Prey size was determined by comparing the prey caught to the length of the birds' bill. Bill lengths were obtained by measuring specimens from the Western Australian Museum. This is a commonly used method of measuring prey size in studies of wading bird foraging ecology (Davis 1985; Recher & Recher 1980).

In addition to foraging observations, wind speed (using an anemometer) and direction, and cloud cover (estimated percentage cover) were recorded for each bird observed. Wind direction was measured with the use of a compass. Disturbances or interference to the birds (such as dogs) that occurred during feeding and resulted in them flying away, were also recorded. The habitat and water depth in which the birds were feeding, were recorded for each strike at prey. The water depth was estimated by comparing it to the known length of the bird's leg. This is a commonly used procedure in foraging ecology studies (Davis 1985; Recher & Recher 1980).

3.2.3 Zoo Foraging

Great Egrets and Nankeen Night Herons forage in numerous areas in the Perth Metropolitan area, including within the Perth Zoo. Egrets and herons seen foraging within the zoo grounds were observed in order to determine the prey caught. These observations were considered incidental, and not part of a structured observational regime. However, they were important in providing information on the extent to which Great Egrets and Nankeen Night Herons nesting at the zoo benefit from food provided to zoo animals. Prey found in nests of Great Egrets and Nankeen Night Herons at the Perth Zoo, and on the ground around the base of the nest, was also collected and identified. These were then compared to food supplied to zoo animals, and to prey caught by the herons at neighbouring wetlands.

3.2.4 Statistical analyses

Statistical tests on foraging characteristics were performed using SPSS Statistical Package with a 0.05 significance level. Foraging observations were often made on the same bird and were therefore not independent. All significant outcomes were therefore treated with less confidence. The overall sample size for Little Egrets was small and therefore any significant results were also treated with less confidence. Differences between prey type and prey size between Great Egrets and Little Egrets were tested using Chi-square analyses and were based on successful strikes only. Three different prey types (worms, crustaceans and insects) were collapsed into one category called 'invertebrates'. Categories were also constructed for prey size, with classes consisting of 0-1, 1.1-3, 3.1-6 and 6.1-14 cm.

Environmental variables, including habitat type, cloud cover, wind speed, wind direction and water depth, and the number of successful strikes were compared between Great Egrets and Little Egrets using Chi-square analyses. Four habitat types were collapsed into three, by combining 'open water' and 'weir wall'. Two water depth classes of '0 to 5 cm' and '16 to 20 cm' were excluded from the analysis to prevent the inclusion of expected frequencies that were too low for statistical analysis. Four categories of cloud cover were used: 0 to 25%, 26 to 50%, 51 to 75% and 76 to 100%. Wind speed was assigned to three categories consisting of 6 to 10, 11 to 15 and 16 to 20 kilometres per hour. The time spent foraging in different water depths was compared for Great Egrets and Little Egrets using a One-way ANOVA.

To determine whether Great Egrets and Little Egrets were more successful in relation to the total number of strikes made, a 'relative success' figure was calculated by dividing the number of successful strikes by the total number of strikes made. The relative success was then compared to environmental variables, including habitat type, cloud cover, wind speed, wind direction and water depth, within Great Egrets and Little Egrets using a One-way ANOVA.

3.3 Results

3.3.1 Morphometrics

Morphometric measurements (Table 9) of Great Egrets and Little Egrets were made using Western Australian Museum specimens (see Appendix 2 for full morphometric table).

Table 9. Mean morphological measurements of Great Egrets (N = 9) and Little Egrets (N = 1) using Western Australian Museum specimens.

Species	Entire bill length (cm) ± SD	Exposed bill length (cm) ± SD	Bill width (cm) ± SD	Tarsus/ Meta tarsus (cm) ± SD	Feather line (cm) ± SD	Foot length (cm) ± SD
Great Egret	14.2 ± 0.8	11.3 ± 0.6	1.5 ± 0.0	13.1 ± 3.1	11.2 ± 2.3	3.2 ± 0.3
Little Egret	10.7	8.5	1.2	9.1	1.5	1.8

3.3.2 Foraging Behaviour

Using Kushlan (1978a) and Recher *et al.* (1983) terminology, twelve foraging behaviours (see Appendix 3 for definitions) were observed for the Great Egret and nine for the Little Egret during this study (Table 10). Great Egrets hunted mainly in upright and partially crouched positions, while standing still. In the upright position, the head and neck were fully extended and erect, and sometimes tilted to the side. In the crouched position, usually observed while perched on a log in the water, the neck was usually withdrawn, and sometimes held against the body. Behaviours, such as neck swaying and foot stirring, were also observed. Great Egrets were mainly solitary foragers, but also fed in mixed species aggregations. The Little Egret hunted mainly in upright and partially crouched positions. More active behaviours, such as running and walking quickly, were also observed.

The Great Egret, in comparison to the findings of Recher *et al.* (1983), exhibited a greater number of foraging behaviours. For example behaviours such as leapfrog feeding, bill vibrating, neck swaying and pecking were observed in this study but not recorded by Recher *et al.* (1983). Piracy was the only behaviour observed by Recher *et al.* that was not observed in this study. The Little Egret, on the other hand, showed less foraging behaviours, where leapfrog feeding, wing flicking and foot stirring were observed by Recher *et al.* and not in this study. Only two behaviours, gleaning and pecking, were exclusive to this study.

Table 10. The presence (+) of foraging behaviours of Great Egrets and Little Egrets in wetlands in the Perth Metropolitan area, 1996 to 1997. Behaviours of the Great and Little Egrets reported by Recher *et al.* (1983) in the Northern Territory are shown (*) for comparison.

Behaviour	**Great Egret**		**Little Egret**	
	This study	**Recher**	**This study**	**Recher**
Stand and wait	+	*	+	*
Crouch and wait	+	*		*
Walk slowly (upright)	+	*	+	*
Scan	+	*	+	*
Walk quickly	+	*	+	*
Running			+	*
Leapfrog feeding	+			*
Wing flicking				*
Foot stirring				*
Following large animals				*
Following other birds	+	*		*
Following large fish				*
Piracy		*		
Feed during day	+	*	+	*
Bill vibrating	+			
Gleaning			+	
Neck swaying	+			
Pecking	+		+	
Probing	+		+	

3.3.3 Prey choice and size

Great Egrets were observed foraging between September and March in 1996 and 1997, for 305 minutes (No. birds = 40; no. foraging observations = 310), and Little Egrets were observed foraging for 24 minutes (No. birds = 6; no. foraging observations = 39). Little Egrets were not observed for as long as Great Egrets because they were less common. Great Egrets spent 69% of the time standing still, taking an average of 11 steps per minute. Little Egrets spent 41% of the time standing still, taking an average of 37 steps per minute (Table 11).

In 305 minutes, Great Egrets were observed striking 491 times at prey, 293 (60%) strikes resulted in the successful capture of prey, the remainder of strikes failing. Overall Great Egrets attempted to capture prey 1.6 times per minute and had one success per minute (Table 11). The main prey captured (63%) by the Great Egret was Mosquito fish (*Gambusia holbrooki*), a locally abundant, introduced species. Insects, crustaceans, tadpoles and worms were also taken (Figure 24).

In 24 minutes, Little Egrets took 99 strikes at prey, 39 (39%) strikes resulted in the successful capture of prey and the remainder were unsuccessful. Overall, Little Egrets attempted to capture prey 4.1 times per minute and were successful 1.6 times per minute (Table 11). The main prey group captured (78%) by the Little Egret was invertebrates. Fish and crustaceans were also taken (Figure 25). There was a significant difference (χ^2 = 36.7, df = 2, p = 0.00) in the prey type between Great Egrets and Little Egrets.

Table 11. Foraging behaviour characteristics of Great Egrets and Little Egrets in wetlands in the Perth Metropolitan area, 1996 to 1997.

	Great Egret	**Mean ± SE**	**Little Egret**	**Mean ± SE**
Number of birds	40		6	
Observation time (seconds)	18316	61.7 ±0.7	1459	39.4 ±3.9
Time spent still (seconds)	12712	42.8 ±1.3	599	16.2 ±2.7
Time spent moving (seconds)	5604	18.9 ±1.1	860	23.2 ±2.5
% of time spent still	69.4%		41.1%	
% time spent moving	30.6%		58.9%	
Number of steps	3253	11.0 ±0.7	892	24.1 ±2.4
Number of steps (per minute)	10.7		36.7	
Number of strikes	491		99	
Number of strikes (per minute)	1.6		4.1	
Number of successful strikes	293	1.0 ±0.05	39	1.1 ±0.2
Number of unsuccessful strikes	198	0.7 ±0.05	60	1.6 ±0.4
Number of prey captured (per minute)	1.0		1.6	
Strike success rate	59.7%		39.4%	

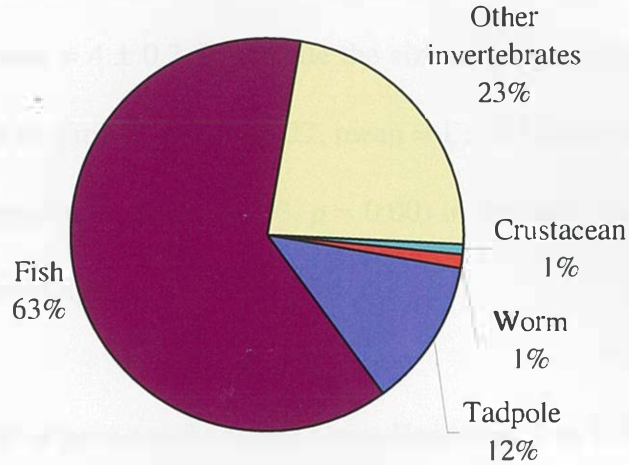

Figure 24. Prey caught (N = 195) by Great Egrets in wetlands in the Perth Metropolitan area, 1996 to 1997. Prey that could not be seen were not included.

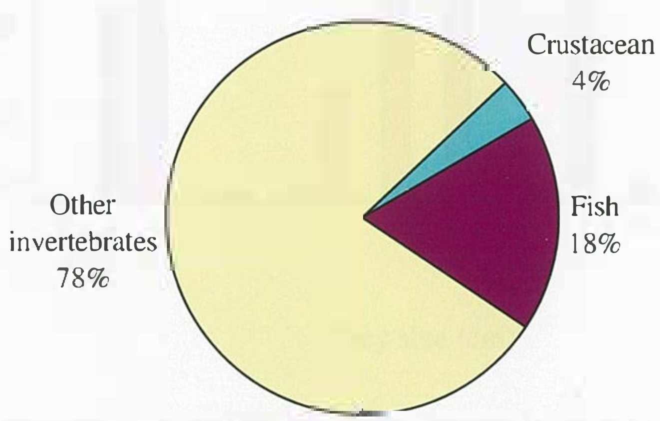

Figure 25. Prey caught by Little Egrets (N = 28) in wetlands in the Perth Metropolitan area, 1996 to 1997. Prey that could not be seen were not included.

The size of prey caught by Great Egrets ranged from less than 1 cm to almost 14 cm in length (N = 217, mean = 4 ± 0.2 SE), while the size of prey caught by the Little Egret ranged from 0.1 cm to almost 5 cm (N = 27, mean = 1 ± 0.3 SE) (Figure 24). There was a significant difference ($\chi^2 = 50.3$, df = 3, $p = 0.00$) in the size of prey caught between Great Egrets and Little Egrets.

Seventy-one percent of prey caught by the Great Egret was 3 to 7 cm in length. Smaller prey were easily caught and swallowed. Larger prey were usually more difficult to consume because of the extra handling required and were often dropped. Most prey (82%) caught by the Little Egret were less than 1 cm in length (Figure 26).

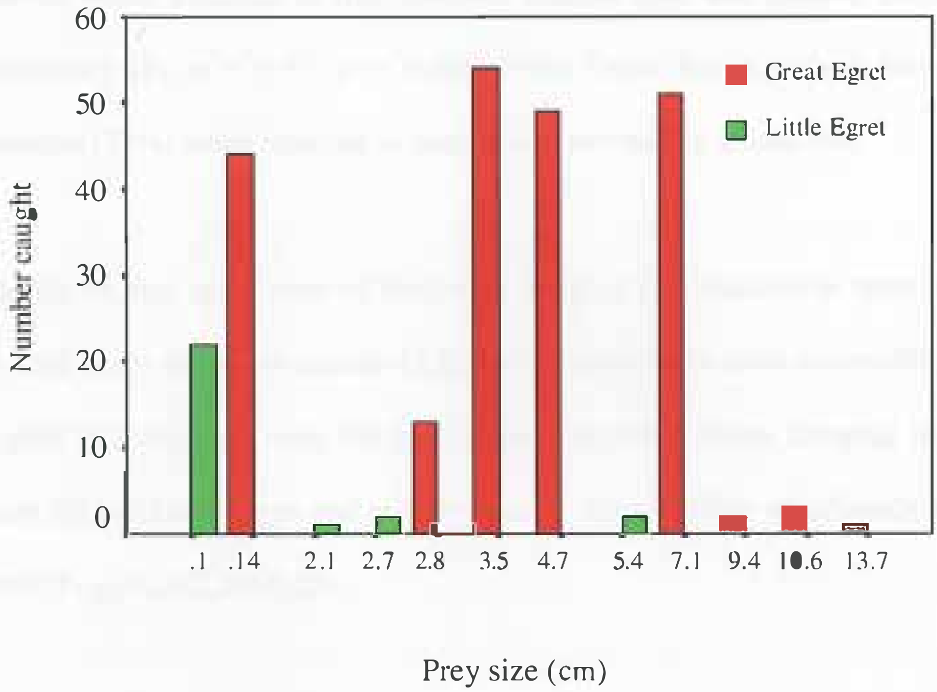

Figure 26. Size of prey caught by Great Egrets (red) (N = 217) and Little Egrets (green) (N = 27) in wetlands in the Perth Metropolitan area, 1996 to 1997. Prey sizes are exact and were determined by comparing prey caught to a known length (obtained from Western Australian Museum specimens) of the birds' bill.

3.3.4 Habitat

3.3.4.1 Habitat type

Great and Little Egrets were observed feeding in a range of habitat types, including open water (usually along the edge of lakes), adjacent to a weir wall (Kent Street Weir) and among reeds. Habitat type and the number of successful strikes differed significantly between Great Egrets and Little Egrets ($x^2 = 57.64$, df = 2, $p = 0.00$). During 305 minutes of observations, Great Egrets (N = 40) foraged most of the time (159 minutes) in open water, but took more strikes per minute (1.8) when foraging in open water perched on a log (Table 12). A 'scanning' behaviour was frequently observed while foraging in this position. Habitat type and relative success differed significantly ($F_{3,197} = 9.97$, $p = 0.00$) within Great Egrets, where they were more successful (70%) when foraging in open water, perched on a dead tree.

Little Egrets also spent most of their time foraging (17 minutes) in open water, where they took more strikes per minute (5.2). Little Egrets were more successful (64%) when foraging in reeds, and were the least successful (36%) when foraging in open water (Table 12) but habitat type and relative success did not differ significantly within Little Egrets ($F_{1,20} = 1.42$, $p = 0.25$).

Table 12. Number of successful strikes made by Great Egrets (N = 40) and Little Egrets (N = 6) in certain habitat types in relation to the time (seconds) spent foraging, in wetlands in the Perth Metropolitan area, 1996 to 1997.

Habitat type	Time (seconds)	Successful strikes (%)	Total strikes (rate per minute)
Great Egret			
Open water/ weir wall	1554	20 (53)	38 (1.5)
Open water	9525	129 (53)	244 (1.5)
Open water/ dead tree	6710	141 (70)	200 (1.8)
Reeds	527	3 (33)	9 (1.0)
Total	18316	293	491
Little Egret			
Open water	1009	32 (36)	88 (5.2)
Reeds	450	7 (64)	11 (1.5)
Total	1459	39	99

3.3.4.2 Cloud cover

Cloud cover and the number of successful strikes did not differ significantly between Great Egrets and Little Egrets (x^2 = 7.56, df = 3, p = 0.06). During 305 minutes of observations, Great Egrets (N = 40) foraged most of the time (212 minutes) in little cloud cover (0-25%), but took more strikes per minute (2.5) when foraging in 26 to 50% cloud cover. Great Egrets were slightly more successful (70%) when foraging in 26 to 50% cloud cover, and were the least successful (58%) when foraging in 0 to 25% cloud cover (Table 13). Cloud cover and relative success did not differ significantly within Great Egrets ($F_{3,197}$ = 1.76, p = 0.16).

Little Egrets spent most of their time foraging (12 minutes) in 76 to 100% cloud cover. They were more successful (64%) when foraging in 51 to 75% cloud cover, and were the least successful (36%) when foraging in 0 to 25% cloud cover (Table 13). Cloud cover and relative success differed significantly within Little Egrets ($F_{2,19} = 4.05$, $p = 0.03$).

Table 13. Number of successful strikes at prey made by Great Egrets (N = 40) and Little Egrets (N = 6) in relation to cloud cover (percent), in wetlands in the Perth Metropolitan area, 1996 to 1997.

Cloud Cover	Time (seconds)	Successful strikes (%)	Total strikes (rate per minute)
Great Egret			
0 - 25%	12724	193 (58)	334 (1.6)
26 - 50%	720	21 (70)	30 (2.5)
51 - 75%	3082	48 (60)	80 (1.6)
76 - 100%	1790	31 (66)	47 (1.6)
Total	18316	293	491
Little Egret			
0 - 25%	296	23 (36)	64 (13.0)
26 - 50%	-	-	-
51 - 75%	450	7 (64)	11 (1.5)
76 - 100%	713	9 (38)	24 (2.0)
Total	1459	39	99

3.3.4.3 Wind speed

Wind speed and the number of successful strikes differed significantly between Great Egrets and Little Egrets (x^2 = 17.33, df = 2, p = 0.00). During 305 minutes of observations, Great Egrets (N = 40) foraged most of the time (94 minutes) and took more strikes (1.9 per minute) in a wind speed of 6 to 10 kilometres per hour. Great Egrets were more successful (62%) when foraging in a wind speed of 6 to 10 kilometres per hour, and were the least successful (57%) when foraging in 16 to 20 kilometres per hour (Table 14). Wind speed and relative success differed significantly within Great Egrets ($F_{2,198}$ = 4.2, p = 0.02).

Table 14. Number of successful strikes at prey made by Great Egrets (N = 40) and Little Egrets (N = 6) in relation to wind speed (kilometres per hour), in wetlands in the Perth Metropolitan area, 1996 to 1997.

Wind Speed (km per hour)	Time (seconds)	Successful strikes (%)	Total strikes (rate per minute)
Great Egret			
6 – 10	5651	109 (62)	176 (1.9)
11 – 15	7017	92 (60)	154 (1.3)
16 – 20	5648	92 (57)	161 (1.7)
Total	18316	293	491
Little Egret			
6 – 10	296	23 (36)	64 (13.0)
11 – 15	1163	16 (46)	35 (1.8)
16 – 20	-	-	-
Total	1459	39	99

Most observations of Little Egrets related to foraging time (19 minutes) in a wind speed of 11 to 15 kilometres per hour, but more strikes per minute (13.0) were made when foraging in a wind speed of 6 to 10 kilometres per hour. Little Egrets were more successful (46%) foraging in a wind speed of 11 to 15 kilometres per hour, and were the least successful (36%) when foraging in 6 to 10 kilometres per hour (Table 14). Wind speed and relative success differed significantly within Little Egrets ($F_{1,20}$ = 8.5, p = 0.01).

3.3.4.4 Wind direction

Wind direction and the number of successful strikes differed significantly between Great Egrets and Little Egrets (x^2 = 232.88, df = 3, p = 0.00). During 305 minutes of observations, Great Egrets (N = 40) foraged most of the time (107 minutes), taking more strikes at prey per minute (1.8), while in a southwest wind. Wind direction and relative success did not differ significantly within Great Egrets ($F_{2,198}$ = 1.67, p = 0.19), although they were more successful (66%) when foraging in a southwest wind, and were the least successful (55%) when foraging in an westerly wind (Table 15).

In 24 minutes of observation, Little Egrets also spent most of their time foraging (12 minutes) in a southwest wind, but took more strikes at prey per minute (13.0) when foraging in an easterly wind. Little Egrets were more successful (64%) when foraging in a northwest wind, and were the least successful (36%) when foraging in an easterly wind (Table 15). Wind direction and relative success differed significantly within Little Egrets ($F_{2,19}$ = 4.05, p = 0.03).

Table 15. Number of successful strikes at prey made by Great Egrets (N = 40) and Little Egrets (N = 6) in relation to wind direction, in wetlands in the Perth Metropolitan area, 1996 to 1997.

Wind Direction	Time (seconds)	Successful strikes (%)	Total strikes (rate per minute)
Great Egret			
Southwest	6446	124 (66)	188 (1.8)
West	6110	90 (55)	164 (1.6)
East	5760	79 (57)	139 (1.4)
Total	18316	293	491
Little Egret			
Southwest	713	9 (38)	24 (2.0)
East	296	23 (36)	64 (13.0)
Northwest	450	7 (64)	11 (1.5)
Total	1459	39	99

3.3.4.5 Water depth

Great Egrets hunted in water from 0 to 28 cm in depth (N = 293, mean = 18 ± 0.4 SE), and Little Egrets hunted in water from 6 cm to 12 cm in depth (N = 39, mean = 10 ± 0.4 SE) (Figure 27). Water depth and the number of successful strikes differed significantly between Great Egrets and Little Egrets ($x^2 = 50.86$, df = 2, $p = 0.00$).

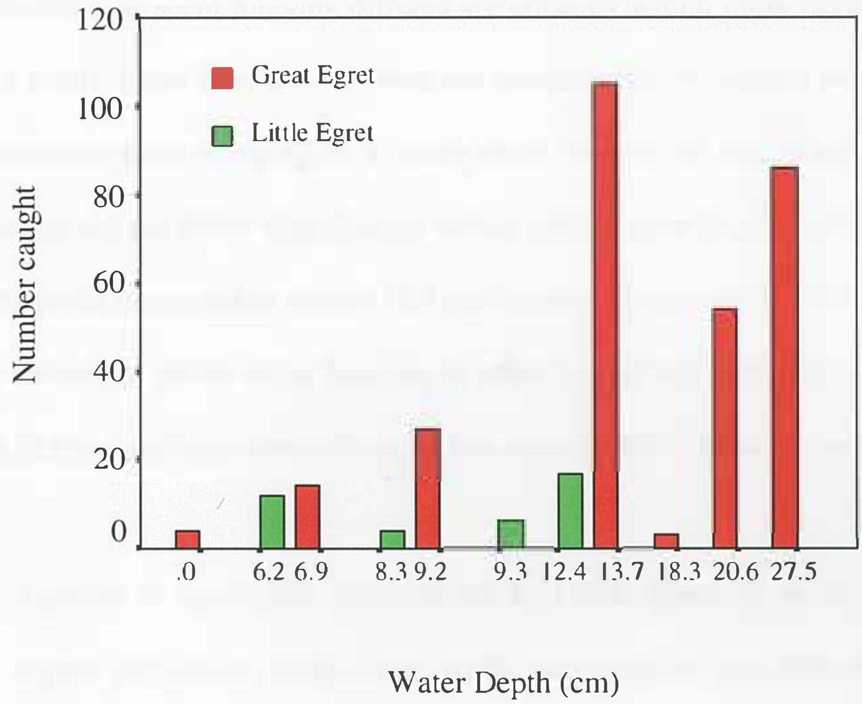

Figure 27. Number of successful strikes at prey made by Great Egrets (N = 293) (red) and Little Egrets (N = 39) (green) in relation to water depth, in wetlands in the Perth Metropolitan area, 1996 to 1997. Water depth measurements are exact and were determined by comparing the depth to a known length (obtained from Western Australian Museum specimens) of the birds' leg.

Water depth and time spent foraging differed significantly within Great Egrets ($F_{4,18311}$ = 253.65, $p = 0.00$). Great Egrets were observed foraging for 305 minutes with the most time (117 minutes) spent in water 14 cm deep. Water depth and relative success did not differ significantly within Great Egrets ($F_{4,196}$ = 1.14, $p = 0.34$). Great Egrets took more strikes at prey per minute (1.8) at a water depth of greater than 20 cm, but were more successful (67%) when foraging on land, and in water 11 to 15 cm (61%) deep. Great Egrets were the least successful at prey capture (56%) when foraging in a water depth of 6 to 10 cm (Table 16).

Water depth and time spent foraging differed significantly within Little Egrets ($F_{4,1457}$ = 152.17, p = 0.00). Little Egrets were observed foraging for 24 minutes with the most time (16 minutes) spent foraging in a water depth of 6 to 10 cm. Water depth and relative success did not differ significantly within Little Egrets ($F_{1,20}$ = 0.95, p = 0.34). Little Egrets made more strikes at prey (6.1 per minute) in water 11 to 15 cm deep, but were more successful (43%) when foraging in water 6 to 10 cm deep. The least number of captures (35%) were made when foraging in a water depth of 11 to 15 cm (Table 16).

Table 16. Number of successful strikes made by Great Egrets (N = 40) and Little Egrets (N = 6) in certain water depths in relation to time spent foraging, in wetlands in the Perth Metropolitan area, 1996 to 1997.

Water Depth (cm)	Time (seconds)	Successful strikes (%)	Total strikes (rate per minute)
Great Egret			
0 to 5	430	4 (67)	6 (0.8)
6 to 10	2694	41 (56)	73 (1.6)
11 to 15	7029	105 (61)	172 (1.5)
16 to 20	240	3 (60)	5 (1.2)
20+	7923	140 (60)	235 (1.8)
Total	18316	293	491
Little Egret			
6 to 10	986	22 (43)	51 (3.1)
11 to 15	473	17 (35)	48 (6.1)
Total	1459	39	99

3.3.5 Disturbances during foraging

During observations, Great Egrets were disturbed 30 times, 19 were from people and dogs, with 11 disturbances from other birds, including other Great Egrets and the Swamp Harrier (*Circus approximans*) (Figure 28). Little Egrets were disturbed once by a person.

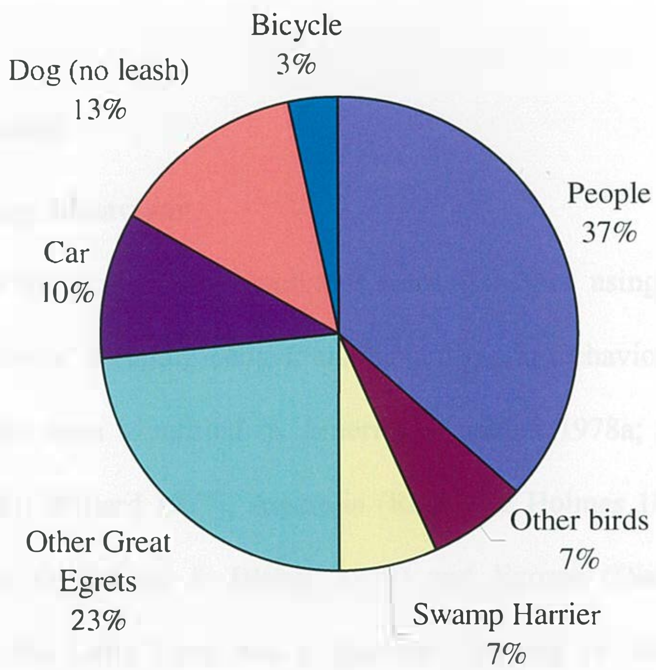

Figure 28. Disturbances to foraging Great Egrets (N = 30), in wetlands in the Perth Metropolitan area, 1996 to 1997.

3.3.6 Zoo foraging

Although not observed taking food from zoo animals, Great Egrets took advantage of wild, live prey that was available in puddles on the zoo grounds. These prey were also found at the base of the Great Egrets nests, including two tadpoles, one frog and one Mosquito fish (*Gambusia holbrooki*).

Nankeen Night Herons were observed stealing food during the day, such as fish and other items, from the Brolga (*Grus rubicunda*) cage most days and from the Australian Bustard (*Ardeotis australis*) cage less frequently. They were also observed taking fish fed to the pelicans (*Pelecanus conspicillatus*) at the zoo lake around 3 pm each day. Food items found at the base of their nests included three crab claws, seven Yellowtail Scad (*Atule mate*) (up to 24 cm long), and two House Mice (*Mus musculus*).

3.4 Discussion

3.4.1 Foraging Behaviour

Great Egrets foraging in Perth wetlands were searchers, using mostly 'stand and wait' and 'walk slowly' foraging behaviours. This foraging behaviour is typical of the Great Egret and has been identified in America (Kushlan 1978a; Recher & Recher 1980; Rodgers 1983; Willard 1977), Australia (Recher & Holmes 1982; Recher *et al.* 1983), South Africa (Whitfield & Blaber 1979) and Europe (Dimalexis *et al.* 1997). In comparison, the Little Egret was a 'pursuer', hunting by 'walking slowly', 'walking quickly' and 'pursuing prey'. This foraging behaviour is also consistent with previous studies (Hancock & Kushlan 1984; Fasola 1986; Recher & Holmes 1982; Recher *et al.* 1983; Rodgers 1983; Whitfield & Blaber 1979).

Although a more active forager, fewer types of foraging behaviour were observed for the Little Egret than for the Great Egret. Although this may be due to the short observation times, these findings are contrary to Kushlan (1978a) and Recher *et al.* (1983). Kushlan (1978a) states that to some degree, a correlation exists between the size of bird and feeding activity. Large birds tend to be less active because of the large energy expenditure required to move, and use standing or walking behaviours, whereas smaller birds engage in many active behaviours. Recher *et al.* (1983) state that more active hunters, such as the Little Egret, have a more diverse foraging behaviour repertoire than less active hunters, and observed Little Egrets in the Northern Territory using a wide range of foraging behaviours.

The correlation of bird size and foraging activity as suggested by Kushlan (1978a) is clear when comparing the foraging data from the present study. Great Egrets spent 69% of the time standing still, taking an average 11 steps per minute while foraging. This is similar to that recorded by Recher *et al.* (1983) in the Northern Territory, where Great Egrets stood still for 77% of the time. The number of steps recorded by Recher *et al.* (1983) however, was less at an average of 5 steps per minute. Whitfield and Blaber (1979) in comparison, observed Great Egrets in South Africa standing still 19% of the time and Rodgers observed Great Egrets in Tampa Bay Florida standing still around 15% of the time. In contrast, the Little Egret spent less time (41%) standing still, taking more (average = 37) steps per minute. Recher *et al.* (1983) observed less active Little Egrets in the Northern Territory standing still 60% of the time, taking 20 steps per minute. Whitfield and Blaber (1979) also observed less active Little Egrets in South Africa spending 60% of their time standing still. Erwin (1985) observed Little Egrets in France taking around 15 to 25 steps per minute. Fasola (1986) found that Little Egrets took around 30 steps per minute. Dimalexis *et al.* (1997) found that Little Egrets in Greece increased their chance of locating prey, because they were more mobile and therefore created more disturbance.

The Great Egret was observed foraging in an aggregation with other wading birds. Kushlan (1978a) and Kushlan (1981) suggest aggregations often form when prey becomes clumped and concentrated. Reduced available habitat was evident at Joondalup Lake, where the water had dried out leaving small patches containing a concentration of prey. The Great Egret possibly aggregated to take advantage of this prey. Recher *et al.* (1983) suggest that herons may follow other birds to take advantage of prey disturbed by them. Kushlan (1978b) also suggests that aggregations increase the birds chance of locating a prey item. Such behaviour has been observed in other wading birds (Davis 1985; Kushlan 1978a; Kushlan 1978b; Master *et al.* 1993) and was observed in the Great Egret in this study. Neither of the egrets was observed hunting regularly in flocks, although this has been recorded for Great Egrets in other studies in Panama (Caldwell 1981) and in the United States (Recher & Recher 1980).

3.4.2 Strike success

Great Egrets observed in this study were quite successful when hunting, catching prey nearly twice out of every three attempts (60%), averaging 1.0 prey per minute. In comparison, Rodgers (1983) recorded a success rate for Great Egrets foraging in Tampa Bay, Florida of 14%. Maccarone and Parsons (1994) recorded a success rate for Great Egrets foraging in New York City of 49% capturing up to 0.3 fish per minute. Recher *et al.* (1983) recorded a success rate of 24% and 0.2 prey captures per minute for the Great Egret in a study of heron foraging behaviour in the Northern Territory. Kent (1986b) suggests that differences in food intake rates are a result of differences in the type and size of prey consumed and its caloric value. The lower success rate recorded in Recher *et al.* (1983) was probably a result of the larger prey being caught, where large prey were often difficult to catch and required more handling time. Smaller prey were caught more frequently explaining the higher number of prey caught per minute recorded in this study, compared to 0.2 prey per minute recorded by Recher *et al.* (1983). In contrast, Master *et al.* (1993) recorded Great Egrets in New Jersey with a higher prey capture rate of 1.6 prey per minute. The density of fish recorded in this study ranged up to 200 fish m^2 which may have accounted for the higher capture rate.

The Little Egret was not as successful per strike as the Great Egret, capturing prey once in every three strikes taken (39%), but had a higher capture rate of 1.6 prey per minute. In comparison, higher success rates and capture rates have been recorded. Erwin (1985) recorded a higher capture rate for the Little Egret in France of 3.2 captures per minute. Kazantzidis and Goutner (1996) recorded a higher success rate for Little Egrets foraging in Greece ranging from 47 to 70% success rate, capturing from 0.6 to 2.8 captures per minute. Hafner *et al.* (1986) recorded a higher success rate for Little Egrets in France of up to 80%, capturing up to 5 prey per minute. In this instance, prey density reached up to 300 individuals m^2. Recher and Recher (1980) and Rodgers (1983) suggest that more active foragers, such as the Little Egret, miss on more attempts at prey capture than searchers, such as the Great Egret. To make up for this lower capture rate, the Little Egret makes more frequent attempts at capturing prey, around four strikes at prey per minute compared with 1.6 strikes per minute of Great Egrets.

3.4.3 Food

Nankeen Night Herons at the Perth Zoo were often observed stealing food supplied for zoo animals. A similar scenario was recorded by Butler (1997), who observed herons at a former Stanley Park Zoo in British Columbia getting handouts of fish from zookeepers tending to penguins. A regular supply of food available within the zoo grounds may account for the species being able to breed all year round, as observed by Spence (1981), and higher nesting numbers compared to the Great Egret. In contrast, Great Egrets only took wild, live prey, available in small puddles in areas in the zoo grounds. The behaviour of the Nankeen Night Herons is highly opportunistic and has been described by Smith (1997) as typical of most ardeids. Recher and Recher (1980, p. 140) state "Herons are opportunists. Given the chance, they will feed on any animal they are able to catch and swallow."

When foraging in wetlands in the Perth metropolitan area, the Great Egret fed mostly on fish. This appears to be a universally common prey choice for the Great Egret (Dimalexis *et al.* 1997; Hancock & Elliott 1978; Hancock & Kushlan 1984; Hoffman 1978; Johnstone & Storr 1998; Maccarone & Parsons 1994; Marchant & Higgins 1990; Miranda & Collazo 1997; Ramo & Busto 1993; Recher *et al.* 1983; Recher & Recher 1980; Schlorff 1978; Smith 1997; Whitfield & Blaber 1979). The Little Egret did not appear to prefer a single prey item. In this study, it fed mostly on insects, whereas in central Italy (Fasola 1994) and the Northern Territory (Recher *et al.* 1983) Little Egrets fed mostly on fish. In South Africa, they fed mostly on crustaceans and gastropods (Whitfield & Blaber 1979), whereas in France, Little Egrets fed mainly on marine crustacea (e.g. Amphipoda, Decapoda and Isopoda) (Fasola 1994) and other crustaceans (Kazantzidis & Goutner 1996). In southern France the Little Egret's main food items were invertebrates and fish (Hafner *et al.* 1986). In comparison, the Snowy Egret, a similar species to the Little Egret in size and behaviour, found in North and South America, fed mostly on fish in New York City (Maccarone & Parsons 1994), Mexico (Ramo & Busto 1993) and New Jersey (Recher & Recher 1980), and prawns (*Palaemonetes* sp.) in Florida (Kent 1986a). The variation in diet of the Little Egret shown in the above studies may be a result of differences in available foraging habitat and the type and size of prey available (Hancock & Kushlan 1984).

Differences in prey choice between the Great Egret and Little Egret were evident, even when exposed to the same prey and foraging in the same place. Recher and Recher (1980) suggest that differences in diet when birds forage in the same place may be a result of the birds' body size and hunting strategies. Larger herons that are searchers should have more diverse diets than smaller herons (Recher & Recher 1980). It is reasoned that their large size allows them to take a greater size range of prey, and using active hunting behaviours allows them to encounter more kinds of prey (Recher & Recher 1980).

Prey caught by the Great Egret in this study varied in size with the maximum prey size almost 14 cm in length. Variations in prey size caught by the Great Egret are apparent in the literature. Ramo & Busto (1993) reported a smaller maximum prey size caught of 6 cm. Recher and Recher (1980) reported a larger maximum prey size of 33 cm in length, Recher *et al.* (1983) reported Great Egrets catching prey up to 15 cm in length, Willard (1977) reported prey being caught up to 36 cm in length, Smith (1997) reported a maximum prey size caught of 18.3 cm in length, and Schlorff (1978) reported Great Egrets taking prey up to 23 cm in length. Recher and Recher (1980) suggest that the size of prey may differ according to their abundance in wetlands where the birds forage. If the frequency of prey caught by the Great Egret is any indication, then it is most likely that small prey were more abundant in Perth wetlands.

In comparison, Little Egrets took smaller prey with the largest being 5 cm in length. Larger herons, such as the Great Egret, are able to take larger prey than smaller herons (Recher & Recher 1980; Whitfield & Blaber 1979) as their relatively longer legs and bills enable them to catch larger, fast-moving prey (Kushlan 1978a; Recher & Holmes 1982). Prey caught by Little Egrets in other studies were similar to that caught in this study. Recher *et al.* (1983) recorded a maximum prey size of 8 cm in length. Observations of the similar Snowy Egret, have shown larger variations in maximum prey size ranging from 4 cm (Ramo & Busto 1993), 11 cm (Smith 1997), 13 cm (Recher & Recher 1980), to 25 cm in length (Willard 1977). Cezilly *et al.* (1988) found that when simultaneously presented with different sized prey, Little Egrets selected larger items which were the most profitable in terms of energy maximisation. Cezilly *et al.* (1988) also suggested that the Little Egret's preference might be interpreted as a higher attractiveness , or greater stimulus, provided by larger prey.

3.4.4 Foraging environment

Habitat appeared to influence the foraging behaviour and striking efficiency of Great and Little Egrets. Great Egrets made the most number of strikes at prey when foraging in open water. Here, the 'stand and wait' and 'walk slowly' behaviours, were used. The high number of strikes made by Great Egrets in open water indicates that small prey were probably more abundant there, as a smaller number of strikes is typical of herons hunting large prey (Recher *et al.* 1983). While the greatest number of strikes at prey was made in open water, Great Egrets were significantly more successful when foraging in open water, perched on a log. Butler (1997) observed similar tactics in Great Blue Herons in British Columbia, which took advantage of objects such as rocky shelves, floating kelp, wharves, and boats to access deeper water to search for prey. By using an object for perching the Great Egret was able to forage in deeper waters than wading would have otherwise allowed. At the same time, potentially disturbing movements to prey caused by Great Egrets during foraging may have been avoided as most of their bodies were out of the water. In contrast, Kazantzidis and Goutner (1996) found a high foraging efficiency is often related to the abundance of available food. Alternatively, this habitat may have contained a greater abundance of smaller prey than other habitats used.

Little Egrets also made most strikes at prey while foraging in open water. Kushlan (1978a) found that smaller herons fed by perching over the water or standing at the water's edge as their morphology inhibited them from wading to any great depth. The majority of prey caught were smaller and in shallower water, more active hunting behaviours such as 'walking slowly' and 'walking quickly' were used. The Little Egret however, was slightly more successful (although not significantly) at foraging around reeds, where they were able to catch numerous invertebrates, a major part of their diet. Dimalexis *et al.* (1997) also found that Little Egrets had more captures per foraging action in wet meadows and marshes, which contained denser vegetation, than riverine habitats.

Other environmental variables, including cloud cover, wind direction and wind speed, influenced the striking efficiency of Great and Little Egrets. Both species were the least successful at prey capture when foraging in no to little cloud cover. Little Egrets were significantly more successful in cloudier conditions. This concurs with Krebs (1974) who found that Great Blue Herons were less successful in sunny weather than in cloudy or rainy conditions possibly due to the effects of glare. In contrast, Rodgers (1983) found no general trend between cloud cover and foraging success on a number of egrets and herons and suggests that more complex variables, such as light intensity, may have contributed. Schlorff (1978) also found that the effect of environmental variables, such as cloud cover, on prey capture rates of the Great Egret were so small that they were of no use as predictors of success.

Wind speed and direction influenced the striking success of the Great and Little Egret in this study. Great Egrets were the least successful at catching prey in strong winds. Recher and Recher (1980) suggest that environmental variables such as wind may interfere with the ability of herons to forage efficiently. Rodgers (1983) concluded that wave height, caused by strong winds, decreased the foraging success of Great Blue Herons and Snowy Egrets. Surface disturbances may disguise any potentially disturbing movements to prey made by Great Egrets during foraging (Davis 1985). In contrast, Little Egrets were more successful in a moderate, northwest wind. As Little Egrets were more active foragers taking more steps while foraging, surface disturbances caused by wind may have served to disguise any disturbances made by the birds while foraging.

Water depth did not affect the relative foraging success of Great Egrets and Little Egrets, where each species was no more successful per strike foraging in a certain water depth. However, Great Egrets spent significantly more time foraging in water approximately 14 cm deep and captured most prey at this depth. Similar foraging depths for the Great Egret have been recorded. Recher and Recher (1980) observed Great Egrets foraging at a mean depth of 13 cm and Whitfield and Blaber (1979) reported a mean depth for the Great Egret of 16 cm. Dimalexis *et al.* (1997) recorded Great Egrets foraging at a mean depth of 14 cm deep. Recher *et al.* (1983) observed Great Egrets foraging in water 15 to 20 cm. In contrast, Willard (1977) observed a mean foraging depth for Great Egrets of 23 cm. Variations in foraging depth, between the studies, are probably a result of the size and type of prey being hunted. In deeper water, Butler (1997) suggests that herons catch more fish than in shallow water. Recher and Recher (1980) and Smith (1997) also suggest that in deeper water wading birds are probably exposed to a greater size range of prey. In this study, Great Egrets fed mostly on abundant small prey, which were typically found in shallower waters where most of their time was spent foraging.

Little Egrets spent most of their time foraging in water around 12 cm in depth. This is slightly deeper than results reported in other studies. Willard (1977) observed Snowy Egrets, a similar sized species, hunting in water averaging 11 cm deep. Whitfield and Blaber (1979) observed the Little Egret foraging in a mean water depth of 10 cm deep. Fasola (1986) observed Little Egrets foraging in water up to 8 cm deep. Recher and Recher (1980) observed Snowy Egrets also foraging in a mean water depth of 8 cm. Dimalexis *et al.* (1997) observed Little Egrets foraging in a mean water depth of 9 cm, while Recher *et al.* (1983) observed Little Egrets foraging in water 5 to 10 cm deep. As expected, the Great Egret hunted in deeper water than the Little Egret. Custer and Osborn (1978a) suggest that larger birds are able to hunt in deeper water and catch greater prey sizes because of morphological differences, such as longer legs and bills.

3.4.5 Disturbances

The majority of disturbances to foraging Great Egrets were a result of human interference in some form. After being disturbed however, the birds usually returned to their place of foraging. Other studies have found that human activities are a major cause of disturbance to breeding and foraging birds and may cause the flushing of birds that are nesting, feeding and roosting, resulting in eventual local abandonment and loss of productivity (Parnell *et al.* 1988).

3.5 Conclusion

The foraging behaviour of the Great Egret and Little Egret was similar to that reported elsewhere in Australia, America, Europe and Africa. Great Egrets were searchers, using mostly 'stand and wait' and 'walk slowly' foraging behaviours, while the Little Egret was a 'pursuer', hunting by 'walking slowly', 'walking quickly' and 'pursuing prey'. The Little Egret is a smaller bird and was hence a more active forager than the Great Egret, a much larger bird (Kushlan 1978a). Great Egrets fed mostly on fish, while Little Egrets fed on a variety of prey types. Great Egrets were able to capture larger fish than Little Egrets, possibly as a result of their larger body size. The Great Egret caught a greater number of prey per attempt than Little Egrets. Their larger size and hunting behaviour also allowed them to take a greater size and range of prey (Recher & Recher 1980). Habitat, cloud cover, wind speed and direction and water depth appeared to influence the foraging behaviour and striking efficiency of Great and Little Egrets. Great Egrets were more successful foragers when perched on an object, which allowed them access to deeper water (Butler 1997). Little Egrets were more successful foraging around reeds, where they could catch numerous invertebrates. Both species were least successful at prey capture when foraging in no to little cloud cover, possibly due to the effects of glare (Krebs 1974; Kushlan 1978a; Whitfield & Blaber 1979). Great Egrets were the least successful at catching prey in strong winds, probably a result of wave height (Rodgers 1983). In contrast, Little Egrets were more successful in a moderate wind, which may have served to disguise any surface disturbances. Great Egrets hunted in deeper water than the Little Egret, a factor of body size and morphology (Custer & Osborn 1978a). Disturbances to Great Egrets when foraging were mostly from humans.

Chapter 4 General Discussion

4.1 Zoo colony status

Jaensch and Vervest (1989), in their study of Great Egret colonies in the southwest of Western Australia from 1986 to 1988, suggested that the breeding population of the Great Egret in the southwest was increasing. Within the Perth Metropolitan area, however, the Perth Zoo is the only remaining Great Egret colony. The number of nesting Great Egrets in the Perth Zoo has increased since Jaensch and Vervest's (1989) counts from 20 in 1988/89 to 49 nests in 1996/97. A small decline in the number of nesting Great Egrets from 49 nests in 1996/97 to 36 nests in 1998/99 at the zoo may be a result of the loss of nesting habitat caused by zoo exhibit expansion, low food availability resulting from low rainfall in the Perth Metropolitan area. Parnell *et al.* (1988) suggests that factors such as these may become important management issues when they adversely affect a species.

In contrast, the number of Nankeen Night Herons nesting at the Perth Zoo increased from 130 nests in 1996/97 to 153 nests in 1998/99. Nankeen Night Herons have been observed breeding all year round (Spence 1981) due to the supplementation of their food supply from within the zoo grounds. Although generally nocturnal foragers they were occasionally observed stealing food which has enabled a gradual increase in their nesting efforts. An increasing presence of the Nankeen Night Heron could eventually inhibit nesting attempts by Great Egrets, through predation of Great Egret hatchlings. Such predation has previously been recorded at the Perth Zoo (Spence 1981).

Nesting habitat of egrets has been shown to degrade with long-term usage, eventually resulting in tree deaths (Belzer & Lombardi 1989). Therefore alternative nesting sites for the Great Egret within the zoo grounds may be needed. Their specific choice of tall nesting trees that provide dense supporting vegetation suggest that future nesting by Great Egrets and to a lesser extent Nankeen Night Herons at the Perth Zoo may be limited. Expansion and construction of zoo exhibits has produced a gradual decline in the number of suitable nesting trees in the zoo grounds, and may already have resulted in a decline in the number of Great Egrets nesting at the Perth Zoo. A strategy to "ensure continual and permanent nesting sites for the Great Egret with ongoing plantings and necessary tree surgery of Canary Island Pine trees" (Crombie 2000, p. 15) has been included in the Perth Zoo Botanical Plan, so no further reduction in nesting habitat should occur. Nankeen Night Herons are more flexible in their choice of nesting habitat and therefore do not appear to have been affected by any reductions in nesting habitat at the Perth Zoo.

4.2 Management within the Perth Metropolitan area

Although Great Egrets and Nankeen Night Herons at the Perth Zoo appeared to be selective in nest sites, they may not have the same nesting requirements elsewhere. Gibbs and Kinkel (1997) suggest that it is unlikely that herons' requirements for nesting substrates are rigid and found that Great Blue Herons nested in a variety of tree species and dimensions. Urbanisation in the Perth area however, has resulted in many wetlands with potential nesting and foraging habitat being drained and filled, or changed by landscaping for human aesthetics. Parnell *et al.* (p133 1988) states 'the greatest threat to colonial waterbirds is the reduction in habitat quantity and quality that is occurring today'. Many wetlands visited in this study had the majority of surrounding vegetation cleared so foraging birds were at risk of being disturbed by people and pets. Loss of fringing vegetation not only has resulted in an increase in human disturbances to foraging birds but also a loss of alternative foraging habitats, such as reeds, logs and other niches. This study has shown how such habitats may increase the foraging success of egrets.

Freshwater wetlands such as Lake Joondalup that are located on a groundwater mound are particularly at threat from excessive groundwater extraction, for use in irrigating gardens and for drinking water. Low rainfall in the Perth Metropolitan area over the last ten years may have contributed towards lowered food availability. This may have affected the number of Great Egret nests in the Perth Zoo. Anderson (1978) found that at Corkscrew Swamp Sanctuary in Immokalee (U.S.A.), drainage of marshlands for housing and agriculture resulted in the reduction of food supply for the Wood Stork (*Mycteria americana*). Fish ponds were then constructed which successfully supplemented the natural food supply of the Wood Stork. Nankeen Night Herons at the Perth Zoo are threatened to a lesser extent by such conditions because their food supply is supplemented by their pilfering of food within the zoo grounds. Other threats to wetlands include weed invasion, introduction of exotic species, rubbish dumping, frequent wildfire, eutrophication from fertiliser runoff and chemical spraying for insect control (Lane *et al.* 1996).

With probable difficulties for Great Egrets and other wading birds in finding other potential nesting sites in Perth city, methods are needed to create new habitats, as well as to preserve and restore existing ones. Fasola and Alieri (1992) suggest the minimum surface area of a wetland that provides suitable habitat for nesting, thereby allowing for the long-term survival of a heronry of a few to about 3000 nests, is four to ten hectares. Jaensch and Vervest (1989) suggest that small wetlands for breeding are not optimal as they are more exposed to storms, human intrusions and predators. Furthermore, such disturbances from humans or predators may result in partial or complete abandonment of breeding colonies (Kelly *et al.* 1993). Using four to ten hectares as a guide, a number of wetlands in the Perth Metropolitan area would be of adequate size for a potential heron colony. All of the lakes visited in this study would be a suitable size for a colony.

Disturbance to foraging and breeding grounds has the potential to negatively affect wading bird colonies and must be taken into consideration when considering creating or restoring breeding and foraging habitats. Great Egrets were often disturbed by humans and pets while foraging at a number of the study sites visited. Carney and Sydeman (1999) suggest however, that wading birds may become habituated to 'visitors', as long as they don't interfere with the colony. This is evident with the Perth Zoo colony, which continues to exist despite the numerous people that visit the area daily. It is likely that tall trees have enabled them to breed without interference. Other effective barriers such as fencing and moats (Carlson & McLean 1996) that prevent human disturbance could also be used. Anderson (1978) also notes how in Louisiana, an island was constructed in a lake and vegetation planted to create potential nesting habitat for a mixed colony of wading birds. As well as providing suitable nesting habitat, the island provided adjacent aquatic food and protection in the form of surrounding water from humans and other predators. It was discovered that the island was used in preference to a linear stand of mature trees that extended for several miles. Fringing vegetation surrounding lakes and wetlands may also act as buffer zones for breeding and foraging Great Egrets and other wading birds, thereby preventing or minimising human disturbance. Rodgers and Smith

(1995) recommended a set back distance of about 100 metres for wading bird colonies to effectively buffer the sites from human disturbance. Pairs of Great Egrets have been known to breed throughout the Perth Metropolitan area, but the Perth Zoo contains the only Great Egret colony. Further research is needed to determine the needs of breeding colonies in order to set up other areas in the Perth Metropolitan area.

Gibbs and Kinkel (1997) suggest the number of herons breeding in a colony is proportional to the availability of foraging habitats near colonies. Storey *et al.* (1993) found that not only do bigger wetlands support more birds, but also wetlands with complex vegetation and higher primary productivity support more birds. Data from this study also suggest that potential foraging sites for the Great Egret and Little Egret in the Perth Metropolitan area should provide a variety of habitat types, including areas of open water of varying depth, patches of reeds and submerged objects. Areas that provide shelter and roosting locations, such as tall trees, are also necessary. Storey *et al.* (1993) suggest that water depth, vegetation structure, pH, dissolved oxygen, chlorophyll *a* and salinity should be measured to provide an indication of changes in suitability of wetlands for waterbirds.

Results from this and other studies suggest that Great Egrets may exchange information and follow each other to profitable feeding sites. By using this information exchange, Great Egrets may be attracted to artificially constructed breeding sites. Parnell *et al.* (1988) found that by using captive parent stock, free-flying wild adults may be stimulated to breed nearby. Artificial attractants, such as decoys, artificial nests and vocalizations, can also be used to help attract nesting birds (Dusi 1985). Any potential breeding sites should however, be located close to the Perth Zoo colony as Wong *et al.*

(1999) found that energetic costs are reduced by flying shorter distances to foraging sites.

4.3 Management Recommendations

1. Regular (preferably annual) counting of Great Egrets and Nankeen Night Herons in the zoo colony and population distribution mapping within the Perth Zoo grounds is needed to provide long-term information on overall population trends for the colony. Disturbance to the colony during counting should, however, be kept to a minimum.

2. If breeding numbers of the Great Egret continue to decline, and the number of Nankeen Night Herons increase, then action may be required. Previously, a translocation of Nankeen Night Herons to other sites in the southwest was undertaken but was not successful as the birds made their way back to the colony (pers comm., Neil Hamilton). Other methods of controlling Nankeen Night Heron numbers may need to be trialed. Parnell *et al.* (1988) suggests that in some cases, killing may be a solution to reduce excessive predation by problem animals. A reduction in food availability in the zoo grounds by covering caged animals' food may serve to regulate Nankeen Night Heron population numbers. There is scope for further investigation of how food supplementation and/or reduction may affect breeding success thereby regulating population numbers.

3. If Nankeen Night Heron population numbers continue to increase, any fallen chicks that survive, although none were observed in this study, should not be rehabilitated and released. Great Egrets on the other hand, frequently had chicks fall from their nests. As there is a lack of information available on the practicality of rehabilitating chicks and

dispersal patterns of Great Egrets, banding and releasing of these surviving chicks may be useful. Any such management options for the colony should be included in the Perth Zoo Fauna Policy.

4. Within the existing colony, planting of Canary Island pines or preferably native species equivalent, may be an option for maintaining and increasing the number of Great Egrets nesting in the Perth Zoo. Tree planting would need to be within the vicinity of the existing nesting trees to provide protection against predators. Despite *Pinus canariensis* being a moderately fast-growing species (Ross 1997) it may take many years for it to reach a suitable height for nesting. There are also limited areas within the zoo grounds where planting could occur, therefore other tree species may need to be removed.

5. Methods to construct breeding and feeding sanctuaries, such as the creation of moats, at Perth wetlands, estuaries and other water bodies should be trialed. Water bodies should, however, be of a considerable size in order to provide a profitable food supply. Mechanisms such as decoys, artificial nests and vocalizations can then be trialed in order to attract birds to potential breeding sites. Where wetlands provide potential nesting sites for egrets and herons but food supply is limited, food supplementation could be trialed.

6. Wetlands where Great Egrets and Little Egrets were observed foraging in this study require rehabilitation to prevent disturbance by humans. Foraging sites that are reachable by humans on foot should be fenced off, or access restricted through the creation of buffer zones by planting of fringing vegetation.

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EGRET NESTS AND CHERRY PICKERS: A CAUTIONARY TALE

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From 1997 to 1998 the reproductive biology of a colony of Great Egrets *Ardea alba* at the Perth Zoo, Western Australia was studied. A cherry picker was used to provide elevation so that an accurate and rapid count of the number of active nests, eggs and chicks, nesting material and the size of nests and position in the trees could be made. The presence of the cherry picker near the Great Egret colony caused seven chicks to fall to the ground, with two of the seven chicks that fell surviving.

Although some mortality occurred, the information obtained using the cherry picker could not have been obtained from observations taken from the ground, due to the height of the nests in the trees. As the colony is the only remaining Great Egret colony in the Perth metropolitan region, an accurate count was necessary to establish a baseline against which long-term fluctuations in numbers could be assessed. The cherry picker counts, although causing several deaths, have allowed the accuracy of previous and future ground counts to be estimated. Long-term monitoring of this colony can therefore be continued from the ground.

Counts of the number of active nests, clutch size and fledging success are necessary to monitor the viability of wading bird colonies. However, accurate counts of the number of nests in a colony are not easily obtained. Wading birds often nest in remote areas, in wetlands where access is difficult and sometimes in tall and thick vegetation (Recher *et al.* 1983). A variety of methods for counting nests have therefore been used, including aerial counts (Baxter 1994; Morton, Brennan and Armstrong 1993) and counts from the ground (Gosper, Briggs and Carpenter 1983). A problem with all procedures is the direct and indirect intrusion into the colony by humans and many authors have noted the adverse effects of such disturbances on wading bird colonies (King 1978; Rodgers and Smith 1995; Vos *et al.* 1985).

During 1997 and 1998, we studied the reproductive biology of a Great Egret *Ardea alba* colony at the Perth Zoo, Perth, Western Australia. As part of this work, we needed information on number of nests, size and building materials of nests, clutch size and number of chicks at different stages of development. In this paper, we report on the use of a cherry picker to collect breeding data on the zoo colony and its effect on nesting birds.

At the zoo, Great Egrets nest in tall pine trees *Pinus canariensis,* with nests ranging from 12 to 29 metres above the ground. To determine the breeding success of Great Egrets, initially the numbers of nests and of chicks within nests were counted from the ground. However, counts from the ground were difficult and inaccurate with repeated counts yielding very different estimates. Counts of eggs were not possible, while chick counts were inaccurate due to visibility difficulties. Tree climbing as an alternative method to ground counts was dismissed as dangerous and likely to be highly disturbing to the birds. As an alternative, and following discussion with persons familiar with the behaviour of nesting herons and egrets, it was decided to use a cherry picker for elevation.

The cherry picker enabled the observer to make an accurate and rapid count of the number of active nests, eggs and chicks, nesting material, and the size of nests and their position in the trees. Three counts using the cherry picker were undertaken each breeding season, for two years. The first counts were undertaken at the beginning of the breeding season in November and repeated fortnightly to mid-December. By December, some chicks were fairly large (nesting was asynchronous) and moving about on the nest and nearby branches. On each occasion, the cherry picker was positioned as far as possible from the nesting trees while still allowing good views of most, if not all, nests. This placed the cherry picker an average 10 metres from the colony. Two persons, the observer and the operator, were required, and both avoided making sudden movements or loud noises which might disturb the birds.

During 1997 and 1998, six counts using the cherry picker were made. On four counts, the presence of the cherry picker caused at least one chick to fall to the ground. In all, seven chicks fell with only two surviving. Chicks that survived needed to be handreared. On 6 December 1998, a camouflage blanket was used to cover the white front of the cherry picker, with the aim of reducing chick mortality. No difference in the behaviour of chicks was observed and three of the seven chicks fell on the occasion. Use of the cherry picker was abandoned after this experience.

Although some chicks fell, the information obtained using the cherry picker could not have been obtained by observations from the ground. Ground nest counts were less accurate and underestimated numbers, sometimes by as much as 10 nests. Eggs could not be seen from the ground and chicks were often concealed, while information on the size and materials used in nests was hard to obtain by ground observations for most nests. On balance, we consider the use of the cherry picker in this colony was justified. The Perth Zoo colony is the only remaining Great

Egret colony in the Perth metropolitan region and is threatened by both development on the zoo grounds and by loss and degradation of the egret's foraging habitat. An accurate count was therefore necessary to establish a baseline against which long-term numbers could be measured. Previous counts (Jaensch and Vervest 1989) had been done from the ground, but their accuracy could not be judged. The cherry picker counts, although causing several deaths, have allowed the accuracy of ground counts carried out in the same season to be estimated. Long-term monitoring of this colony can therefore be continued from the ground. Based on our experience, a cherry picker should only be used in heronries when other census methods are not possible or where standardization of procedures is significantly important (as at the Perth Zoo) to justify possible losses of chicks.

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Appendix 2

Morphological measurements, using Western Australian Museum specimens, for the Great Egret, Little Egret and Nankeen Night Heron.

Species	Bird number	Entire bill length (cm)	Exposed bill length (cm)	Bill width (cm)	Tarsus/ Meta tarsus (cm)	Feather line (cm)	Foot (cm)
Great Egret							
	A1423	12.6	10.4	1.46	12.2	8.9	2.9
	A12308	14.6	12	1.47	7.7	14.1	3.1
	A12312	14.4	11.5	1.46	14.4	8.9	3.4
	A12310	14.5	11.5	1.46	8.6	15.3	3.7
	A1423	14.2	10.6	1.54	14.9	10.5	3.2
	-	15.1	12.4	1.47	16.2	10.5	2.9
	2773	13.3	10.8	1.43	13.3	8.9	2.7
	A12313	13.9	11.1	1.43	14.4	12	3.5
	A4404	15	11.2	1.44	16	11.8	3.4
Little Egret							
	10891	10.7	8.5	1.19	9.1	1.5	1.8
Nankeen Night Heron							
	A14116	12.2	6.4	1.2	7.4	2.6	4.1
	A4634	11.1	5.8	1.0	6.3	1.7	3.4
	8737	13.0	7.3	1.1	7.5	3.4	4.1
	A1276	13.3	7.0	1.0	7.3	2.6	3.8
	235	13.5	7.8	1.1	7.3	3.1	4.5

A8277	13.1	7.0	1.1	7.7	1.3	3.9
A4821	13.1	7.6	1.2	8.0	1.3	4.3
	12.1	7.3	1.1	7.2	2.5	4.1
433	13.3	7.9	1.0	7.5	2.6	4.4
496	13.9	8.2	1.1	8.1	2.7	4.8
A18736	13.8	7.7	1.2	7.8	3.8	4.2
A8446	12.8	7.3	1.2	7.4	3.1	3.8
A12277	12.1	6.7	1.0	7.6	2.0	3.6
319	13.6	7.5	1.0	8.3	3.1	4.2
10724	13.2	7.0	1.1	7.6	2.9	4.2
	14.2	7.4	1.0	8.3	3.4	4.0
A3260	12.8	6.8	1.0	7.2	2.7	3.8
962	11.4	6.8	1.1	7.7	2.8	3.4
509	13.4	7.6	1.1	8.1	1.9	3.8
10894	13.4	7.5	1.3	8.0	2.7	4.3

Appendix 3

Foraging behaviour definitions from Kushlan, (1978) and Recher *et al.*, (1983).

Behaviour	Description
Stand and wait	Stands erect in one place
Crouch and wait	Bends down in one place
Walk slowly (upright)	Walks at slow speed
Scan	Upright posture looking for prey
Walk quickly	Walks at relatively fast speed
Running	Moves quickly
Leapfrog feeding	Flies from back of feeding flock to front
Wing flicking	Quickly partially extends and retracts wing
Foot stirring	Vibrates foot or leg
Following large animals	Following grazing mammals to take advantage of other prey disturbed
Following other birds	Following other birds to take advantage of other prey disturbed
Following large fish	Following large schools of predatory fish to take advantage of other prey disturbed
Piracy	Steal prey from other birds
Feed during day	Feeding during day time
Bill vibrating	Rapidly opens and closes bill in water
Gleaning	Catches prey located on an object (e.g., rocks, shells, dung) to feed underneath
Head swaying	Moves head from side to side out in water, in either slow or rapid sweeps

Neck swaying	Moves neck and sometimes body from side to side out of water
Head swinging	Moves bill from side to side in water
Pecking	Picks up item from substrate
Probing	Quickly and repeatedly moves bill tip into and out of water or substrate
Hopping	Flies short distance and alights
Hovering	Hovers over water or ground, picking up prey
Dipping	While flying outs head down and catches prey
Plunging	Dives headfirst from air
Swimming feeding	Swims or floats on surface of water