Human Disturbance to Colonially Breeding Seabirds and Guidelines for Visitor Management on Islands off the Coast of Western Australia.

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DECLARATION

I declare that this thesis is a product of my own research and acknowledgements of other work have been made where appropriate.

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ABSTRACT

Islands off the south west coast of Western Australia are becoming increasingly popular as destinations for tourism and recreation. Many species of Australian and pelagic seabirds use these small, nearshore islands as seasonal or permanent breeding grounds, as most lack land-based mammalian predators. An assumption of allowing recreation and tourism on many of Western Australia's A-Class Nature Reserves is that human visitation does not disturb breeding seabirds.

Human disturbance to colonially breeding seabirds is an issue becoming increasingly relevant as human coastal populations and visitor numbers to islands continue to grow. The degree of impact human disturbance may have on a seabird breeding colony is dependant on species-specific behavioural responses to a perceived predator, the phase of the nesting cycle and the potential for habituation.

This study tested these hypotheses using an approach-retreat sequence on the Australian Pelican (*Pelecanus conspicillatus*), the Greater Crested Tern (*Sterna bergii*) and the Brown Noddy (*Anous stolidus*).

Findings verify that: (1) responses to human approach varied between species, (2) responses varied over two phases of the nesting cycle and (3) tolerance increased over time indicating short-term habituation in Australian Pelicans and Greater Crested Terns.

Differences in response were measured using the distances at which birds changed their behaviour as a result of human approach and the time taken to return to normal incubating behaviour after an approach. It was found that the latter was an important indicator for measuring the impacts of human disturbance, particularly for highly tolerant species such as the Brown Noddy that showed very little physical response during an approach.

Findings from this research suggest that interactions between humans and these species should be managed through encouraging predictable, regular and frequent human activity through the use of walkways and interpretive signage. Setback distances for these species should be established by adding the CAD’s measured during the most sensitive phases of breeding (early incubation or nest building phases) around known seabird breeding habitats and locations. In this way interactions between humans and breeding seabirds can be minimised.

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DEFINITIONS

Active Activity	an activity that involves the modification of the surrounding environment
Alert Distance	the distance between a bird and an intruder at which the bird makes some visible or measurable response
Approacher	person walking towards the breeding colony
Buffer Zone/ setback distance	an area beyond which people minimally disturb or impact wildlife
Critical Approach Distance	the distance at which a person can approach a bird without eliciting anti-predator or flight behaviour
Displacement Behaviour	behaviour that is unrelated to the situation in which it occurs
Flight Initiation Distance	the distance at which a bird actually leaves the site where it is nesting
Habituation	the relatively persistent waning of a response as a result of repeated stimulation which is not followed by any kind of reinforcement
Intention Movements	seabird behaviour that shows the intention of flight
Intraspecific	confined within the species
Mass Up-flight	greater than 50% of a colony taking off in flight
Passive Activity	an activity for which the surrounding environment is the focus
Philopatric	the tendency for young to return to their natal colony
Pre-flight Distance	the distance of the approacher away from the colony edge recorded as the point immediately preceding flight of the target bird
Relaxation Time	the time taken for an the target individual and immediate neighbours to return to normal behaviour following a disturbance
Return Time	the time taken for the flushed bird to return to the nest site and resume incubating
Seabird	a bird that derives most of its sustenance from the sea
Shorebird	a bird that lives, feeds and breeds on the shore of a water body

Site Attachment	the tendency to return to a site following disturbance during a nesting cycle
Site/Colony Fidelity	tendency for a breeding individual to return to the same site in successive breeding attempts
Tolerance	the intensity of disturbance than an individual bird tolerates without responding in a defined way / tendency to accept intruders
Tourist	a person who has traveled to a destination to take a holiday
Visitor	a person visiting a destination for reasons other than a holiday (includes those pursuing recreational activities)
Waterbird	a bird that lives, feeds and breeds in or near water (includes shorebirds and seabirds)
Waypoint	closest point of first approach without causing mass (<50%) up-flight (set into a Global Positioning System)

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1. INTRODUCTION

1.1 Background

Visitor management is a growing concern (Jim 1989), particularly for small islands, restricted in space and limited in resources. An issue that is becoming increasingly relevant to scientists, conservationists and land managers globally relates to human disturbance to breeding waterbirds, and more specifically seabirds. The heightened popularity of islands amongst tourists and increasing human activity on small nearshore islands and coastlines is causing biologists and natural area managers to examine more closely the effects this growth has on the breeding success of seabird populations.

Seabirds breed on islands for a number of reasons, but primarily to avoid land-based mammalian predators (Burger and Gochfeld 1991, Dunlop and Rippey 2001). Studies show that seabirds can be sensitive to human activity, particularly during their breeding season (for example Burger and Gochfeld 1994, Giese 1995, WBM Oceanics and Claridge 1997, Giese and Riddle 1999, Nisbet 2000). As the number of people visiting islands increases, so does the potential for seabird disturbance and the adverse impacts that often result. These impacts may include increases in predation, loss of eggs and young to heat and cold, reductions in juvenile provisioning and site desertion (Burger and Gochfeld 1994, Giese 1995, Carney and Sydeman 1999, Nisbet 2000, Lord *et al* 2001).

Humans can affect breeding seabirds in a number of ways. Disturbance may involve approach by car, boat, and plane or on foot, or in a more direct way through habitat modification or destruction. Globally there have been numerous studies that contribute to the broad knowledge base on human disturbance of breeding seabirds, the negative impacts on their breeding success and possible management recommendations to remedy these (examples include Anderson and Keith 1980, Burger and Gochfeld 1994, Blackmer *et al* 2004).

However, in Australia and particularly Western Australia there are significant data gaps, with an extensive literature search turning up only one Western Australian based study that investigated these issues in any detail (Dunlop 1996). However, due to increasing coastal development and the popularity of Western Australia's beaches and nearshore islands for tourism and recreation, it is becoming more important to gain an understanding of how recreation and tourism could be influencing the breeding behaviour of seabirds, to ensure the survival of local breeding populations.

The Department of Conservation and Land Management (CALM) have noted this lack of information in Western Australia and recommend in their draft management plan for the islands of the Turquoise Coast that the Critical Approach Distances (CAD's) of seabirds using these islands to breed should be investigated (CALM 2001). A CAD is defined in this context as the distance at which breeding seabirds can be approached without causing escape or anti-predator behaviour (Dunlop 1996). It is a term that incorporates a range of measures, from the distance at which a bird first responds to approach, to the distance at which it flushes from its nest.

Knowledge of CAD’s has been utilised in several studies to create management guidelines for heavily visited areas, ensuring minimal negative impacts to breeding seabirds while maximizing the viewing experience of the visitor (Erwin 1989, Giese 1997, Rodgers and Smith 1997, Ronconi *et al* 2002).

However CAD’s have been found to vary between species, with the mode of human transport, over geographically separated populations, at different stages of the breeding season and with varying histories of human disturbance (Keller 1989, Nisbet 2000, Dunlop and Rippey 2001, Gill *et al* 2001). This indicates that while CAD’s may be useful for managing the interactions between humans and breeding seabirds, they must be based upon site-specific information.

The Western Australian coastline is important for numerous species of breeding seabird, including the Australian Pelican (*Pelecanus conspicillatus*) on Penguin Island, the Greater Crested Tern (*Sterna bergii*) on Rottnest Island and the Brown Noddy (*Anous stolidus*) on Lancelin Island. These species are considered to have particular ecological and conservation significance, and/or are thought to be sensitive to human disturbance. Furthermore, the islands on which these species breed are already, or are becoming increasingly popular as tourist destinations. Rottnest Island for example has over 500, 000 visitors annually (RIA 2003), Penguin Island over 80, 000 (Louissa Liddicoat pers comm) and Lancelin Island a much smaller (perhaps in the order of a few thousand), but nevertheless increasing amount (Nic Dunlop pers comm).

1.2 Project Rationale, Aims and Objectives

As there has been little work done in Western Australia on the responses of breeding seabirds to human disturbance, it is important to develop a database that can be fed into the management process. Additionally, it is widely viewed that different species and in some cases breeding populations show varying responses to human intrusion and therefore it is necessary to gain an understanding of site specific details to ensure appropriate management techniques are employed.

This study aims to test the behavioural reactions of three Western Australian breeding seabird populations to a person approaching via land and on foot to gain an understanding of these responses and how they may differ between species, over stages of the breeding season and over time. This information will then be used to establish CAD’s for each species and stage of the breeding season and to formulate management recommendations for each species to aid CALM in managing human activities on seabird breeding islands.

The specific aims of this project are to:

1) **Review the issues surrounding human visitation to seabird breeding islands.**
2) **Develop an understanding of how selected species respond to human approach in three different island settings.**
3) **Assess the significance of this information in relation to managing visitation to seabird breeding islands.**

Embodied within these aims are several objectives. These are to:

1) Identify the potential impacts of human disturbance to breeding seabirds and why these occur through a review of relevant literature.
2) Document the behavioural responses of Australian Pelicans (*Pelecanus conspicillatus)*, Greater Crested Terns (*Sterna bergii*) and the Brown Noddy (*Anous stolidus)* to human approach through the following research questions:
    - Behavioural responses to human disturbance will vary between species.
    - Behavioural responses to human disturbance will vary over different stages of the breeding season.
    - All species will show increased tolerance (short-term habituation) to successive human approaches.
3) Estimate the Critical Approach Distances (CAD's) for the above three species.
4) Develop management guidelines with respect to these three species.

1.3 Thesis Structure

This thesis is comprised of seven chapters. Chapter One introduces the topic and the specific research aims, objectives and research questions.

Chapter Two consists of a literature review, which explores typical seabird breeding behaviour and how it relates to the impacts caused from human disturbance to breeding colonies. It also reviews the types of impacts that may result from disturbance and explain the methods used to manage or reduce negative interactions between people and breeding seabirds on islands. This chapter also gives some examples of previous studies of critical approach distances to waterbirds and the general management guidelines that have been recommended.

Chapter Three describes the three islands on which these seabirds breed. It details site-specific information including management practices, visitation regimes and an outline of the local breeding seabirds.

Chapter Four outlines the methods employed to carry out the approach experiments including the experimental design and statistical analyses. Chapter Five details the results of the approach experiments set out in Chapter Four. These findings along with management recommendations and suggestions for further studies are discussed in Chapter Six and conclusions are outlined in Chapter Seven.

2. LITERATURE REVIEW

2.1 Introduction

Islands are highly desired as destinations for tourism and recreation and their attraction is increasing worldwide (Newsome *et al* 2002). The kinds of uses favoured are nature observation (such as in the Galapogas and on Cousin Island, Seychelles), permanently developed tourism (such as resorts and hotels on Heron Island, Australia), and recreational activities that includes water sports, picnicking, walking, fishing and boating (Diamond 1985, Walker 1991, Revitt and Sanders 2002). However some of these activities, (namely developed tourism and recreational activities, but in some cases ecotours and bird watching) are arguably unsuitable for small islands, particularly those vested as nature reserves, as they disturb breeding seabirds (for example Walker 1991, Lord *et al* 2001, Sekercioglu 2002).

Many species of seabird nest colonially on small islands to avoid mammalian predators and to be close to their feeding grounds (Burger and Gochfeld 1991, Powell and Collins 2000). Furthermore, through their gregarious and conspicuous nature, nesting seabirds and their activities draw the attention of human visitors (Anderson and Keith 1980). A number of studies show that colonial seabirds on islands can be sensitive to human intrusion or approach, particularly during their breeding season (for example Kury and Gochfeld 1975, Anderson and Keith 1980, Giese 1995, WBM Oceanics and Claridge 1997, Giese and Riddle 1999, Nisbet 2000).

Some of the impacts that can occur as a result of disturbance by human approach include colony desertion, interruption of breeding/courting, increased egg and chick mortality through predation, exposure or trampling and physiological stress to adults (for example Hockin *et al* 1992, Burger and Gochfeld 1994, Giese 1995, Carney and Sydeman 1999, Nisbet 2000, Lord *et al* 2001). Many interactions are not necessarily considered to be adverse unless they have a further or cumulative effect upon the breeding success, adult survival or size of the breeding population (Kury and Gochfeld 1975, Walker 1991, Yalden 1992, Burger and Gochfeld 1998, Nisbet 2000, Gill *et al* 2001). Whether breeding success has or has not been affected by human disturbance is in some studies an issue that needs further investigation.

Several studies outlining management guidelines for breeding or feeding waterbirds suggest the use of Critical Approach Distances (CAD's) to establish 'setback distances' around colonies known to be aversely affected by human activities (for example Rodgers and Smith 1995, Giese 1997, Richardson and Miller 1997, Rodgers and Smith 1997). Developed by these authors, measures may vary depending upon the species itself, the stage of the breeding season, geographic location, the type of disturbance, the degree to which habituation has occurred, flock size and angle of approach (Anderson and Keith 1980, Cooke 1980, Dunlop 1996, Nisbet 2000, Dunlop 2002, Blumstein *et al* 2003). The physical size of the birds may even be an important factor (Cooke 1980). CAD's may be particularly important for managing human-seabird interactions on small islands due to resource limitations such as space. If employed to regulate people's movement CAD's may ensure that human activities do not disturb breeding seabirds while maximizing the space and recreational experience available to visitors.

This review considers the impacts of human disturbance to breeding seabird colonies on islands, whether these impacts have been shown by the literature to have had a significant adverse effect on breeding success or adult survival and how they could be managed. It will firstly examine typical seabird breeding behaviour to give the reader an understanding of why particular impacts occur as a result of human visitation. Impacts, and management guidelines aimed at reducing them will then be explored in the second half of the review. As there are few studies that specifically look at breeding seabirds on islands, other relevant literature encompassing colonial waterbirds (freshwater) and shorebirds have been included in this review.

2.2 Seabird Behaviour and Human Disturbance

Human disturbance is defined by Bolduc and Guillemette (2003) as an activity that causes a change in behaviour and/or metabolism in an animal. In the context of human disturbance, seabirds often perceive humans as if they were potential predators (Gill *et al* 1996), as they sometimes are.

Seabirds respond to human disturbance in a variety of ways, their response being dependant upon factors such as the type or form of disturbance (active consisting of a modification of the surrounding environment and passive for which the surrounding environment is its focus), geographical location, habitat, history of disturbance, the degree of site tenacity and the displacement and anti-predator behaviour a species exhibits (Anderson and Keith 1980, Hockin *et al* 1992, Dunlop 1996, Nisbet 2000, Dunlop 2002). Many studies additionally conclude that the stage of the breeding season has an effect on the behavioural response to disturbance (Kury and Gochfeld

1975, Anderson and Keith 1980, Burger and Gochfeld 1991, Carney and Sydeman 1999, Gill *et al* 2001, Bolduc and Guillemette, 2003).

2.2.1 Types of human disturbance

People approach breeding seabirds for a number of reasons. These include tourism and recreation, nature observation and for research purposes (Diamond 1985). Disturbance by an investigator or researcher has been documented for over forty years. This type of disturbance is caused by the approach, nest checking, handling and observation of seabirds in order to learn more about the effects this may have on their productivity and how to manage these impacts (Kury and Gochfeld 1975, Rodgers and Smith 1995, Rodway *et al* 1996).

People engaging in recreational activities often disturb breeding seabirds without necessarily knowing it. They may be participating in such activities as walking, bike riding, playing sports, boating, surfing or picnicking near or in a breeding site, unconsciously impacting upon the birds’ feeding and breeding behaviour and/or physiology (Yalden 1992, Knight and Cole 1995, Lord *et al* 2001)

In other cases, people actively seek out breeding colonies in order to view or photograph wildlife. Wildlife tourism is becoming increasingly popular throughout the world as more and more remote locations are visited for their wildlife attraction (for example the Galapagos Islands, Kenchington 1989, Burger and Gochfeld 1993). Several studies caution the idea that negative impacts are not occurring when they cannot be seen (for example Giese 1995, Higham 1998, Gill *et al* 2001), and some suggest that ecotourism or wildlife tourism may potentially be damaging to the wildlife that the industry depends upon (Burger and Gochfeld 1993, Higham 1998, Orams 2002).

The studies reviewed in this case dealt primarily with the effects of investigator approach on foot, as they were by far the most common (for example Giese 1996, Giese 1997, Bolduc and Guillemette 2003, Gyuris 2004) and it is thought that pedestrian approach is often more disturbing than those made by vehicles or boats at the same distance (Henson and Grant 1991, Pers obs). Increasingly however, research on the effects of wildlife and ecotourism and incidental visitor disturbance is being published, and several of these studies were included in this review to ensure that a broad range of human disturbances were addressed (for example Burger 1981, Keller 1989, Burger and Gochfeld 1998, Higham 1998, Sekercioglu 2002).

Impacts resulting from human activities are dependant upon stimulus intensity, (ie: active or passive activity and the numbers of people participating in them), frequency of occurrence and the duration of stay. The majority of reports indicate that the types of disturbance having the potential to impact significantly on breeding seabirds, (other than the development of permanent hotels and resorts) is intense (highly active with large numbers of people participating) and infrequent (Diamond 1985, Hockin *et al* 1992, Carney and Sydeman 1999, See Figure 2.1).

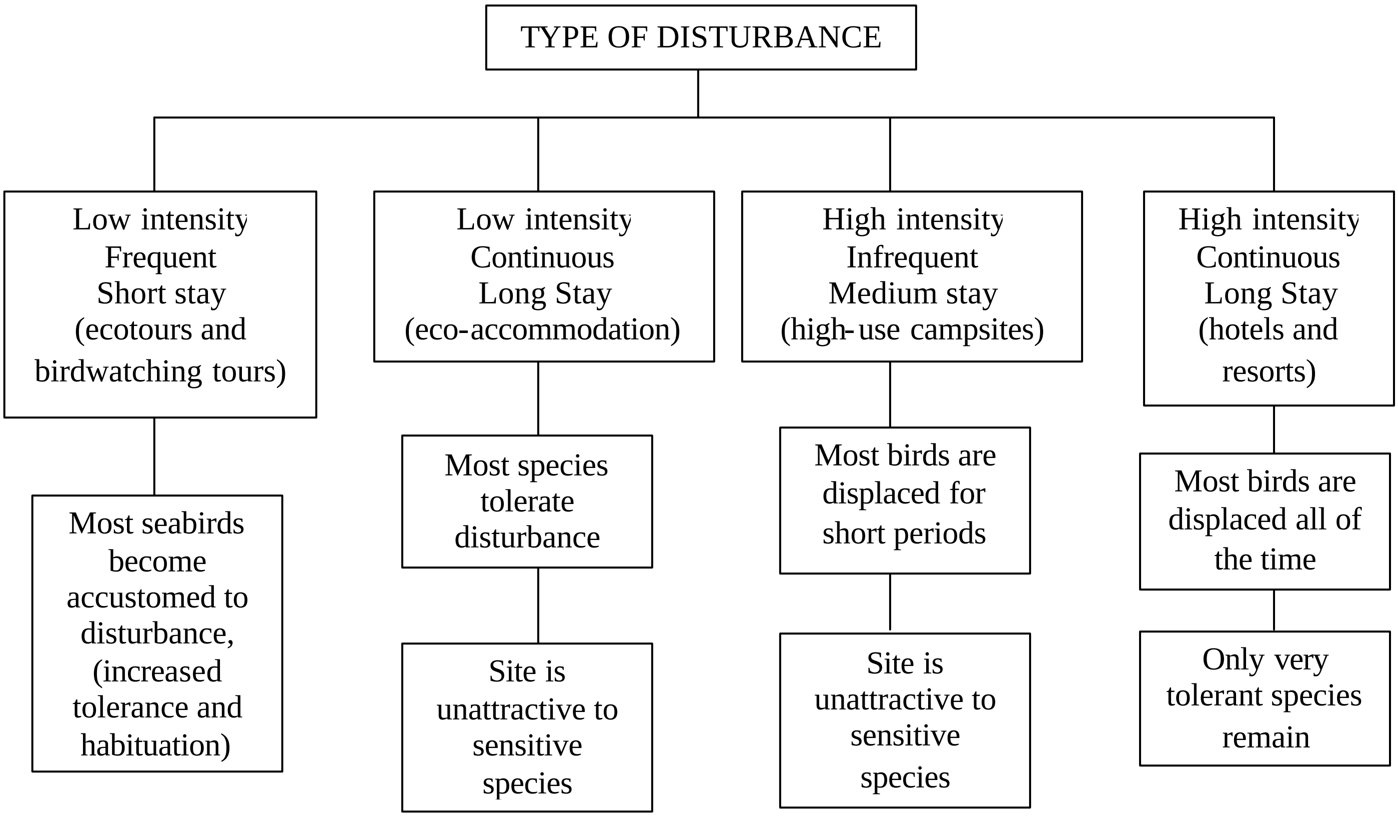

Figure 2.1- *Types of human disturbance according to their intensity and frequency of occurrence (adapted from Hill et al 1997)*

The types of human use that have the lowest impact are frequent, low intensity activities over short periods of time (Dunlop and Rippey 2001). The increased frequency of events can in many cases facilitate habituation of seabird colonies, reducing the effects human disturbance has on their breeding behaviour still further, however this is only the case when the activity is of relatively low intensity (Keller 1989). An example is a recent study by Gyuris (2004) which suggests that frequent visitation is more advantageous to breeding Bridled Terns (*Sterna anaethetus*) than infrequent visits as the negative effects of human intrusion were ameliorated by increasing habituation. However some studies maintain that frequency of disturbance has little consequence to changes in breeding success (for example Bolduc and Guillemette, 2003).

2.2.2 Anti-predator strategies: synchrony, concealment, colonial breeding

Anti-predator behaviour may be divided into two categories: direct and indirect. Direct behaviour includes avoidance and site defence, the latter is often associated with species that exhibit a high degree of site fidelity. Indirect anti-predator behaviour includes breeding synchrony, or the simultaneous timing of laying amongst the colony, common in species with low site/colony fidelity (Dunlop 1986, Burger and Gochfeld 1994, Dunlop and Rippey 2001) (See Figure 2.2).

Colonial breeding occurs in most seabird species (Burger and Gochfeld 1991). In fact, Furness and Monaghan (1987) state that some 98% of all seabird species typically nest in colonies. It may be an effective adaptation as it simultaneously facilitates predator defence and early predator detection and decreases the amount of time individuals must devote to vigilance (Furness and Monaghan 1987). Coloniality may also facilitate breeding synchronization, thus effectively 'swamping' predators with eggs and young and reducing an individual's risk of predation (Dunlop 1987, Furness and Monaghan 1987, Coulson 2002, Sekerioglu 2002). A third benefit is thought to be the transfer of information on the whereabouts of food supplies (Furness and Monaghan 1987).

In a review by Burger and Gochfeld (1994) it was suggested that terns, larids and penguins had a higher success rate in colonies than they achieved on their own. However there are some disadvantages of colonial breeding, these being competition for food, increased risk of disease or parasites and increased intraspecific predation, aggression and interference (Coulson 2002). Additionally, colonies of breeding seabirds are particularly vulnerable to human disturbance as they are often highly visible and remain in a fixed location (Burger *et al* 1995).

Aggressive or evasive behaviour in seabirds is a characteristic of species with strong site attachment and a high level of nest concealment, and is facilitated by colonial breeding (Burger and Gochfeld 1991). If disturbed these species will 'mob' the intruder, or distract predators from eggs or young through mass up-flight, (the simultaneous flight of birds within a colony) (Burger and Gochfeld 1994). Species that fall into this category include Bridled Terns and Silver Gulls (*Larus novaehollandiae*). Crypsis, or the camouflage or eggs and nests, is additionally used as a mechanism for evading predation, and is of particular benefit to species that lay their eggs in widely spaced nests, (Burger and Gochfeld 1994) (See Figure 2.2).

Figure 2.2 shows the relationships between types of anti-predator behaviour and site attachment, habituation and susceptibility to human disturbance among species from the south west of Western Australia. Synchrony, concealment and site defence are all strategies that minimise individual losses to predators. These adaptations are present in varying degrees within different species as shown along the scale from those with high site fidelity and low susceptibility to human disturbance, to low site fidelity and high susceptibility.

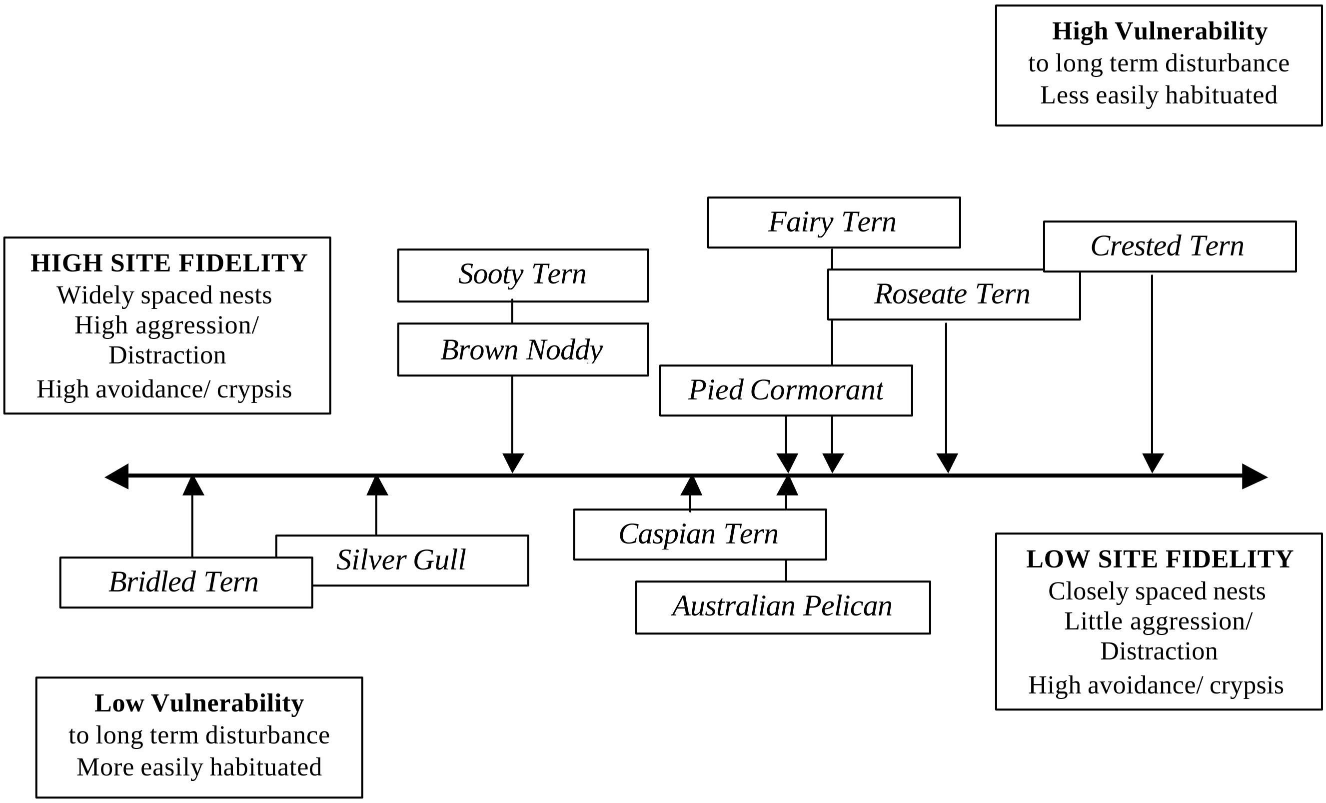

Figure 2.2- *Anti-predator strategies and their relation to site fidelity in Western Australian species. (Based upon data provided by Nic Dunlop).*

2.2.3 The importance of site fidelity and site attachment

Site fidelity is tendency for a breeding individual to return to the same site in successive breeding attempts. Site attachment is the tendency to return to a site following disturbance during a nesting cycle (Nic Dunlop pers comm).The primary importance of understanding site fidelity in different species is its use as an indicator of species sensitivity to human disturbance. Strong site fidelity and attachment can facilitate habituation whereas weak site fidelity and attachment provides little opportunity to habituate and often site desertion results in response to human approach (Nic Dunlop pers comm). Knowing the level of site attachment of a species allows managers to devise appropriate management strategies to protect sensitive species and habituate tolerant ones.

In many seabird species, particularly larids (gulls and terns) the relationships with nest sites are varied and depend upon a range of adaptations (such as crypsis, defence and synchrony) to minimise the risk of predation (Dunlop and Rippey 2001). These adaptations determine the level of site fidelity and attachment that a particular species exhibits (Dunlop and Rippey 2001). It is generally viewed that species with low site fidelity are more susceptible to human disturbance than those with high, as they may respond to disturbance by abandoning breeding attempts, potentially relocating or perhaps not breeding again that season (Kury and Gochfeld 1975, Nisbet 2000, Dunlop and Rippey 2001, Blackmer *et al* 2004). Examples of these species include Greater Crested Terns (*Sterna bergii*), Roseate Terns (*Sterna dougallii*), Fairy Terns (*Sterna nereis*) and Caspian Terns (*Sterna caspia*) (Dunlop and Rippey 2001). Species with high site fidelity such as Brown Noddies (*Anous stolidus*), Pacific Gulls (*Larus pacificus*) and Silver Gulls, Bridled Terns and Sooty Terns (*Sterna fuscata*) are considered less vulnerable as they will rarely abandon a site if disturbed. It is this ‘perseverance’ with disturbance that can facilitate tolerance and eventually habituation to the process of human intrusion (Nisbet 2000, Dunlop and Rippey 2001) (See Figure 2.2).

However, Gill *et al* (2001) hypothesise in their short review paper on the behavioural responses of birds to human disturbance, that a birds’ readiness to leave a site may not be an adequate measure of how sensitive a particular species is to disturbance. It may in fact be a measure of how many other suitable sites the population has to choose from, and the cost of moving in terms of energy budgets. Gill *et al* (2001) also state that birds more able to move away may in fact do so at a lesser cost than those that are forced to stay in heavily disturbed conditions. Their study primarily considers non-breeding waterbirds, however its findings may be relevant to breeding seabirds. In support of Gill *et al* (2001), West *et al* (2002) surmises that when the time and energy costs of disturbance are factored in, human disturbance may be more damaging than habitat destruction. These conclusions provide alternative views to that which is described in Figure 2.2 as it may in fact be that high fidelity species are equally vulnerable, particularly in the short term, if they are forced to breed in areas visited intensively by humans.

Many studies have found that site attachment varies according to the stage of the breeding cycle, where the highest level of attachment is exhibited around hatching (eg: Kury and Gochfeld 1975, Carney and Sydeman 1999, Nisbet 2000 and Gill *et al* 2001). However Erwin (1989) found no differences in the responses to human disturbance of nesting waterbird colonies through the nesting cycle, but did state that early prospecting and courting could be affected. These findings have implications for the management of visitation, indicating that caution should be exercised in allowing visitor access early in the breeding season, as disturbance impacts such as site desertion may be more likely to occur during this time. This caution may extend to a complete or partial ban on visitation during such a time if it is desirable for a particular species to breed on a particular island.

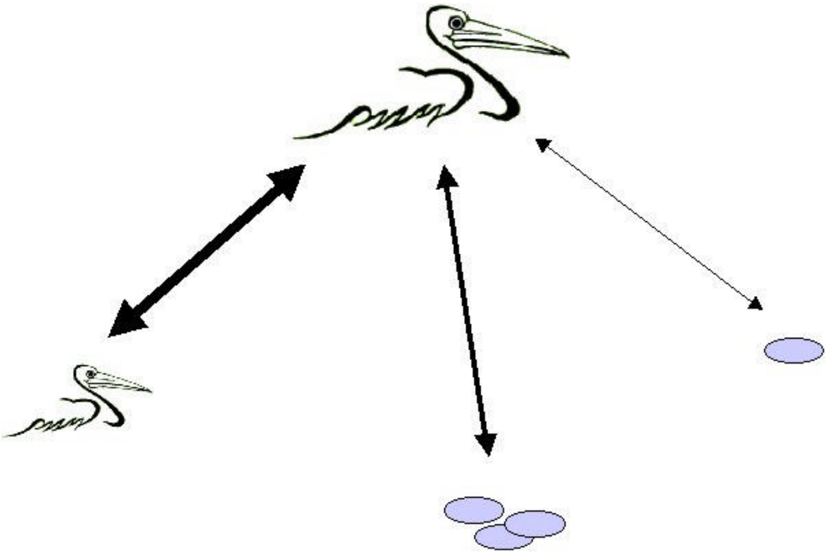

Figure 2.3- Diagram showing site attachment as a positive feedback system. The thickness of the arrow indicates the degree of site attachment.

2.2.4 Habituation

Habituation in birds is the dampening of flight responses (Dunlop and Rippey 2001) or the relatively persistent waning of a response as a result of repeated stimulation, which is not followed by any kind of reinforcement (Burger *et al* 1995, Nisbet 2000). Burger *et al* (1995) state that it is an adaptive response to avoid spending unnecessary energy and time reacting to a benign stimulus. In many studies, habituation is said to have occurred when birds nesting or feeding in areas highly frequented by humans show less of a response to the approach of humans than do birds in more remote locations (Cooke 1980, Keller 1989, Burger and Gochfeld 1991, Metcalf *et al* 2000, Nisbet 2000, Gill *et al* 2001, Lord *et al* 2001).

Many species of seabird regard humans as potential predators and thus attribute similar responses to our approach as they would to that of any other land predator

(Gill *et al* 1996). Habituation is thought to occur in individuals as they experience a series of repeatedly benign interactions with humans, and consequently ‘learn’ that humans pose no threat to their safety (Nisbet 2000). However the effects of habituation should not be confused with varying levels of tolerance. High tolerance to human disturbance in seabirds is associated with those species possessing weak anti-predator responses (eg: pelagic/oceanic species) or when birds are strongly site attached. Often seabirds that show no overt fear of humans are assumed to show the effects of habituation however habituation cannot be distinguished in the field without knowledge of natural tolerance levels, past levels of disturbance and the behavioural patterns of a particular species (Higham 1998, Nisbet 2000).

While much of the literature makes reference to “habituation effects”, often this is a result of finding no overt response. Several papers (for example WBM Oceanics and Claridge 1997, Higham 1998, Gill *et al* 2001, Lord *et al* 2001) caution the idea that a lack of response indicates no impact, as behavioural or physiological changes may go unnoticed. Examples include elevated corticosterone levels in Magellanic Penguins (*Spheniscus magellanicus*) (Fowler 1999), increased heart rates in the Adelie Penguins (*Pygoscelis adeliae*) of Antarctica (Giese 1995) and use of sub-optimal nesting habitat in Common Terns (*Sterna hirundo*) in New Jersey (Burger 2003).

Consequently, there is some debate as to whether habituation is desirable in colonial breeding seabirds. Keller (1989) found that Great Crested Grebes (*Podiceps cristatus*) that were more highly habituated to human passage would not cover their nests before they flew away, causing an increased rate of predation, while Orams (2002) reported negative effects of habituation on food provisioned wildlife in general. On the other hand, Burger and Gochfeld (1991), Nisbet (2000), Dunlop (2002) and Gyuris (2004) state that habituation should be maximised to reduce negative impacts from human disturbance that arise from mass up-flight. Their view is that habituation has the potential to be a useful management tool, allowing breeding colonial seabirds and human activities to occur within close proximity, without a high level of impact on the seabirds and often with educational benefits for visitors. However individual bird behaviour must be closely monitored to detect any changes that might indicate further reactions to disturbance.

It is often difficult to encourage habituation on very small islands because a minimum distance is required between the birds and the visitor to allow habituation to develop. To assist habituation of seabirds, visitor behaviour should be benign and predictable while visits should be short, frequent and in small groups (Burger 1981, Carney and Sydeman 1999, Dunlop and Rippey 2001, see Figure 2.1). Habituation in unlikely when events are sporadic or in species that exhibit low site fidelity (for example Caspian Terns), as they will often leave a disturbed site whether human behaviour is benign or otherwise (Giese and Riddle 1999). Management decisions on whether to encourage or discourage habituation in breeding seabirds are important as they will ultimately direct all aspects of visitor movement and island infrastructure.

However different studies have uncovered differences in behavioural responses within the same species over different locations. For example, Dunlop (1996) examines the differences in behavioural response in breeding Bridled Terns on Bridled and Penguin Islands. He shows that Bridled Terns on Penguin Island are perhaps the most tolerant seabird to use this island as a breeding ground, and that they have habituated to human activity over a number of years. Conversely, it is suggested by WBM Oceanics and Claridge (1997) that Bridled Terns are one of the most sensitive species to human disturbance (found on the islands of the Great Barrier Reef) and should be allowed the largest buffer. These variations in responses highlight the need to examine seabird reactions to human activity on a population scale where habituation may be a factor. Some authors support the theory that observed habituation should not alter the minimum approach distances assigned to that particular species so that physiological effects may be minimised (Rodgers and Smith 1995, WBM Oceanics and Claridge 1997). However in many cases, habituated birds will themselves move closer to human boundaries (Nic Dunlop, pers comm.) thus implying that negative effects must be minimal.

2.3 Impacts of Human Disturbance to Colonially Breeding Seabirds

Disturbance of colonially breeding seabirds during their breeding season has the ability to negatively affect their breeding performance, distribution and energy budgets (Schultz and Applegate 1998). There have been numerous studies made on the effects of human disturbance to waterbird breeding success, and many of these cite human disturbance as having adverse effects on varying elements of the breeding success of several species (Ollason and Dunnet 1980, Pierce and Simons 1986, Henson and Grant 1991, Yalden 1992, Burger and Gochfeld 1994, Giese 1995, Carney and Sydemen 1999, Leseberg *et al* 1999, Cannel 2001, Lord *et al* 2001, Ikuta and Blumstein 2002, Bolduc and Guillemette 2003, Blackmer *et al* 2004).

Seabird breeding colonies often show spontaneous panic reactions due to natural disturbances, such as predatory birds or thunder (Pers obs). While the response to human approach is similar to normal anti-predator behaviour, human disturbances have been known to last longer than those caused by natural factors, and consequently may ultimately have an increased impact on juvenile recruitment (WBM Oceanics and Claridge 1997).

There is a wide range of impacts linked to reduced breeding success that can occur as a result of human disturbance to breeding seabirds on islands. Much of the literature gives examples such as increased predation, over-exposure of young and nest desertion by adult breeding pairs (for example Anderson and Keith 1980, Carney and Sydeman 1999).

However, it should be noted that impacts such as these may not always be adverse to the overall reproductive success of the population experiencing them (Kury and Gochfeld 1975, Walker 1991, Burger and Gochfeld 1998, Gill *et al* 1999, Nisbet 2000). Whether or not these changes have been shown to significantly affect the reproductive success of a colony is a subject of some contention, as none of the studies reviewed have been capable of taking into account the multitude of confounding factors that additionally influence reproductive success, nor apply them to the entire breeding population (for example: Anderson and Keith 1980, Giese 1995, Leseberg *et al* 2000).

However, it is important to have some understanding of possible impacts that could occur as a result of introducing or allowing visitors to island breeding colonies. Below some of the more common effects of human disturbance are described.

2.3.1 Breeding site desertion

Breeding site desertion has been found by Anderson (1988) to be directly related to the proximity of human activity, meaning that the closer people approach breeding colonies, the more likely a disturbance resulting in desertion will occur. Breeding site desertion is commonly recorded among species without fixed nest sites (or that exhibit low site fidelity, Dunlop and Rippey 2001) and particularly when birds are disturbed early on in the breeding season (Bolduc and Guillemette 2003). Desertion is more prevalent at early stages as energy investment and the cost of abandonment is at its minimum (Dunlop and Rippey 2001). Furthermore, species with low site fidelity may have several other potential sites to move to, whereas adults of species with fixed nest sites are not predisposed to shift nesting locations (Gill *et al* 2001). West *et al* (2002) state that breeding site desertion may be comparable with habitat loss for those species that do not habituate to disturbance.

Most of the literature studied indicates that seabirds are more sensitive to disturbance by humans earlier in the breeding cycle and cannot be closely approached (Kury and Gochfeld 1975, Anderson and Keith 1980, Hockin *et al* 1992, Rodway 1996, WBM Oceanics and Claridge 1997, Carney and Sydeman 1999, Nisbet 2000, Gill *et al* 2001). For example when Californian Brown Pelicans (*Pelicanus occidentalis californicus*) and Double-Crested Cormorants (*Phalacrocorax auritus*) were disturbed early, their nest sites were abandoned for the remainder of the season, (Kury and

Gochfeld 1975, Anderson and Keith 1980). Whereas those that were disturbed during fledging sat tight on their nests and allowed a closer approach (Kury and Gochfeld 1975). Walker (1991) suggests that in fact most species will abandon nest sites if disturbed at an early period, although a similar study states that the phase of the nesting cycle was not significantly related to differences in response for a mixed colony of Common Terns (*Sterna hirundo*) and Black Skimmers (*Rynchops niger*) (Erwin 1989).

Species with low site fidelity will change breeding locations between each season, keeping to a broad natal area (Dunlop and Rippey 2001). These are the types of species that are considered by many to be particularly susceptible to human disturbance as they will commonly abandon one nesting attempt and relocate to another area, (Anderson and Keith 1980, Walker 1991, Hockin *et al* 1992). Birds displaced by disturbance may additionally put pressure onto otherwise undisturbed birds as they move to other breeding areas (West *et al* 2002). This could be in the form of increased competition for food, nest sites or spread of parasites (West *et al* 2002).

Site desertion is not only relevant to species with low site fidelity, but can effect those that are otherwise highly philopatric to their nest sites. In a study by Blackmer *et al* (2004), 37% more pairs disturbed once a daily and weekly than control pairs of Leach's Storm-petrel (*Oceanodroma leucorhoa*) deserted the nest burrows that they had used the previous year. This may have had a significant negative impact on the long-term breeding success of this colony, as changing nest sites often results in changing mates.

Site abandonment is classified by most researchers as a process detrimental to the reproductive success of a colony, particularly for those species that do not lay replacement clutches (Anderson and Keith 1980, Rodway 1996, Blackmer 2004). Furthermore, Dunlop (1987) and Burger and Gochfeld (1994) stress that secondary breeding attempts may not be as productive if laid later in the breeding season and replacement clutches are often smaller and less viable. However none of the studies reviewed accurately document reduced breeding success due to site desertion, as none have been able to measure the net decrease in productivity, the influence of other factors (such as food availability), the energy cost of relocating and whether second attempts are indeed made.

2.3.1 Increased predation and exposure to the weather

Predation can be higher on islands than on the mainland due to limited space and resources (Burger and Gochfeld 1994). Additionally, human disturbance can influence the population of predators and increase the incidence of predation in colonies by flushing adults from their nests (Burger and Gochfeld 1994). Predation is the most documented impact of human activity in or around seabird breeding colonies.

Leaving nests upon the approach of a predator may be an adaptation to reduce the vulnerability of adult and young to predation and is common amongst most tern species (Lord *et al* 2001). Studies have shown that although adults quite often leave their nests under natural circumstances, they do not travel from them as far and for as long a period of time as when humans disturb them (Keller 1989, Henson and Grant 1991). Additionally some waterbirds have been documented as not covering their eggs well when disturbed, further increasing the likelihood of predator or exposure (Keller 1989, Henson and Grant 1991). Predators in these cases are usually other birds that are more tolerant to human disturbance (such as gulls or corvids (ravens)) than are the birds of the colony and are allowed the opportunity of increased predation because of human presence (Kury and Gochfeld 1975, Liddle 1997).

A number of studies examine the results of human intrusion in relation to predation. For example Kury and Gochfeld (1975) described Great Black-Backed Gulls (*Larus marinus*) and Herring Gulls (*Larus argentatus*) patrolling the outskirts of a cormorant colony until human intrusion gave them access to eggs and young. They also reported that in an experiment that lasted 1 hour, 17 of the 96 King Shag (*Phalacrocorax albiventer*) eggs were taken by Dolphin Gulls (*Leucophaeus scoresbii*). The study identified that these gulls associated human disturbance with food, and as they were not as sensitive to disturbance as were the cormorants and shags, were able to predate more heavily than had humans not intruded.

Predation of eggs and young is, in many breeding colonies, the factor having the largest potential impact on breeding success, as adults must firstly evade predators themselves while secondly protecting their eggs and young (Burger and Gochfeld 1994). Predation can be exacerbated by human disturbance, through predator provisioning, (eg: humans feeding silver gulls in Australia) and therefore increasing their numbers to beyond natural levels, and through physically interrupting birds' brooding, allowing predators to access unguarded nests (Kury and Gochfeld 1975, Anderson and Keith 1980, Ollason and Dunnet 1980, Giese 1995). For example Giese (1995) found that disturbed colonies of penguins were less likely to resist predator attack than undisturbed colonies, while Kury and Gochfeld (1975) found that human disturbance could have a significant effect on cormorant numbers through increased predation. A literature review by Sekercioglu (2002) on the impacts of bird watching revealed that an increase in egg loss due to predation was a common result in several separate cases.

Up-flight or flushing experienced by the majority of seabird species during disturbance not only results in increased predation but exposure of eggs and young to the elements (Burger and Gochfeld 1994, Giese 1995). None of the studies identified document the number of fatalities through over-exposure to heat or cold, and this is generally only an issue in very hot or very cold climates. However Giese (1998) reported decreased hatching success in Adelie Penguins that were exposed to nest checks and recreational visits, with eggs being cooled up to 3.9 °C. Chicks are also susceptible to hypo or hyperthermia, especially from hatching up to four weeks of age (Nelson 1980).

2.3.2 Reduced provisioning of young

Reduced provisioning refers to the reduction in time spent by adults searching for food and feeding their young. Several studies make reference to changes in adult and chick foraging or social behaviour as a result of human activity (Burger 1981, Burger and Gochfeld 1993, Lord *et al* 1997, Thomas *et al* 2003). The importance of these behavioural changes is that they can often have further implications for the amount of time and energy spent in feeding young. For example, adults that leave the nest as a result of human disturbance do so using time that would normally be spent foraging or feeding young and expend energy defending their young through aggression or avoidance. In addition, the number and regularity of feeding events may be reduced to sub-optimal levels and weight gain may become variable, potentially having an effect on growth rate, fledging weight and in one example by Pearce-Higgins and Yalden (2002) chick survival (Giese 1995, Lord *et al* 1997, Thomas *et al* 2001). Consequently human disturbance may reduce the ability of adults to satisfy both their own energy demands as well as those of their young (Leseberg *et al* 2000).

Additionally, human disturbance may also result in young birds or adults regurgitating fish as a distraction mechanism for predators. Kury and Gochfeld (1975) found that cormorants would regurgitate fish when disturbed. This operated on the gull's preference for fish rather than eggs and thus reduced the threat of nest predation. However there was consequently less food available to young, as regurgitated fish is not identifiable as a food source for many species of seabird (Nic Dunlop, pers com.). Anderson and Keith (1980) recorded juvenile brown pelicans regurgitating fish when attacked by gulls after disturbance. The same study has recorded juvenile pelicans being pecked by gulls, causing blindness or disembowelment, eventually leading to death.

2.3.3 Physiological stress and increased energy costs

There are several papers that advocate caution when studying wildlife disturbance, as a lack of behavioural changes may not necessarily indicate a lack of disturbance (for example Giese 1998, Gill *et al* 2001, Lord *et al* 2001). Physiological stress and increased energy costs are increasingly being recognised as impacts of disturbance, however further studies are required to determine just how much of an impact stress can have on breeding seabirds.

Physiological stress on breeding seabirds and its effect on their overall survival is a topic that comparatively little is known about. The most knowledge concerns penguins in cold climates. Giese (1998) outlines the possible significance of stress on the breeding success of Adelie Penguins in Antarctica. She found that an approach by an observer to within 5 meters often did not register a behavioural change, but heart rate increased significantly above natural alert levels. Lord *et al* (2001) also advocates caution when approaching northern New Zealand Dotterels (*Charadrius obscurus aquilonius*), as physiological responses such as elevated corticosterone levels may result from infrequent visits.

Physiological stress increases energy consumption and heat loss, which is needed for incubation, (especially in cold climate species) and may impact on hatching success (Whittow and Rahn 1984, Henson and Grant 1991, Giese 1995). The increase in energy usage through moving off nests or the increase in heart rates when disturbed can be fatal in times of food shortages, as the energy lost through disturbance cannot be replaced (Knight and Cole 1995, Thomas *et al* 2003).

Energy costs may also result from the use of sub-optimal habitat (due to avoidance) and reduced time foraging (Thomas *et al* 2003). Fledging chicks are especially vulnerable as they are reliant on the food brought by their parents and require an energy surplus to reach a suitable fledging mass. A reduction of this optimal weight could lead to a reduction in recruitment for that year (Giese 1995).

2.4 Measurement of Human Disturbance to Breeding Seabirds

2.4.1 Changes in breeding success

Human disturbance to seabird breeding colonies is considered to be truly detrimental if the reproductive success of the colony or adult survival is undermined (Nisbet 2000). Several studies that have shown reductions in the breeding success of colonies have not been capable of measuring the overall productivity (net adult output over a number of years) of a disturbed colony, instead choosing to focus on hatching or fledging success, egg loss or adult survival for a particular year or season (for example Anderson 1988, Rodway *et al* 1996, Bolduc and Guillemette 2003, Blackmer *et al* 2004).

There are additionally several confounding factors that need to be taken into account in such studies if an accurate measure of the reduction in breeding success is to be obtained. For example, climate and weather have an enormous effect on food supply and thus the success of populations (Burger and Gochfeld 1994). Many studies do not differentiate between natural mortalities and those caused by humans so there can be no certainty that perceived reductions are the sole result of human disturbance (for example Anderson and Keith 1980, Giese 1995, Bolduc and Guillemette 2003).

However this is not to say that breeding success is not affected by the impacts described above. There is good evidence that many of these impacts resulting from human disturbance, (mainly recreational) can have both immediate and long-term effects on the reproductive success of local populations (some recent examples include Lord *et al* 2001, Ikuta and Blumstein 2002, Bolduc and Guillemette 2003, Blackmer *et al* 2004). Reduced breeding success is well documented in Double-Crested Cormorants, Pelicans and Adelie Penguins (Nisbet 2000).

Researchers into the effects of human disturbance on the breeding success of waterbirds often choose to study a representative measure of overall productivity. For example, studies that have used measurements of hatching or fledging success include Anderson and Keith (1980), Giese (1995) and Bolduc and Guillemette (2003). These studies used counts to determine the numbers of nest failures, eggs that were predated or hatchlings that reached 3-4 weeks old and recorded desertions and adult mortalities. While these types of measurements give an indication of seasonal breeding success, they do not allow us to make statements about the impact that disturbance has on the lifetime reproductive output of individuals. A consistent reduction in this output would eventually result in the decline of the population.

2.4.2 Changes in behavioural response

A review of relevant literature suggests that behavioural response is the most commonly used indicator of impacts resulting from human disturbance. The majority of studies that measure the effect of disturbance on nesting colonial seabirds use behaviour to determine whether disturbance could be having an effect on productivity (for example Henson and Grant 1991). These studies often use flushing or up-flight as the behavioural change which indicates disturbance, and monitor the distance at which this occurs from the observer. (Examples include Erwin 1989, Burger and Gochfeld 1993, Rodgers and Smith 1995, Blumstein *et al* 2003). Although in a recent study by Fernandez-Juricic *et al* (2001), ‘alert distance’ was used experimentally as an indicator of disturbance.

Behavioural response is linked in many studies to actual observed impacts, such as increased predation, juvenile death and exposure of young (Kury and Gochfeld 1975, Anderson and Keith 1980, Bolduc and Guillemette 2003). In other studies these impacts are not always observed or recorded, but are noted by the authors as being highly probable (Erwin 1989, Giese 1995). For example in a review by Henson and Grant (1991), there were no measured differences in the productivity between disturbed and undisturbed Trumpeter Swans (*Cygnus buccinator*) however behavioural differences provoked speculations on ‘unseen’ impacts.

Thus by observing behaviour, it is often possible to make predictions about the impacts that may result from human approach, without actually having to measure them directly.

Some researchers claim that behaviour may not be a reliable way to measure impacts resulting from disturbance. Gill *et al* (2001) states that recording behavioural changes to human presence could be an unreliable method for determining the susceptibility of a particular species to disturbance, as there are several other factors that affect how a bird perceives humans and responds to a threat. These include food availability, (seabirds will often take flight earlier if there are food shortages), habituation, and the species itself (Giese 1995, Giese 1998, Dunlop and Rippey, 2001).

Thus using behavioural response as an indicator of impacts is still a useful and convenient way to investigate and monitor the effects human disturbance may have on the breeding success of seabird species. This method may be used by managers to gain a broad understanding of the susceptibility of certain species to disturbance and the best ways in which to minimise negative impacts.

2.5 Critical Approach Distances and their Relevance to Management

Jim (1989) states that visitor management serves two main purposes. Firstly, it can reduce visitor impacts on the surrounding environment and wildlife, and secondly it can aid in the enhancement of the recreational experience of the visitor. These concepts apply to the management of visitation to seabird breeding islands, where knowledge of seabird behaviour, Critical Approach Distances (CAD's) and the establishment of setback distances can be used to protect breeding colonies from the adverse effects of human disturbance while optimising the experience of the visitor (for example Rodgers and Smith 1997).

As mentioned in section 2.1, a CAD is the distance at which a visible intruder illicits avoidance behaviour (Dunlop 1996). Human intrusion within a species' CAD often constitutes a disturbance, and in general, the closer the disturbance, the more severe the behavioural reaction of the individuals within the colony (Burger and Gochfeld 1993, Giese 1998).

Several studies have chosen to use Flight Initiation Distances (FID's) or Flushing Distances as a measure of disturbance (for example Burger and Gochfeld 1991, Rodgers and Smith 1995). However, a broader term such as Critical Approach Distance may be more useful to managers as it may encompass these terms, but is not limited to them in terms of quantifying a distance at which disturbance occurs. For example, Thomas *et al* (2003) employed 'Minimal Approach Distances', which determined how close a human could get to a foraging sanderling (*Calidris alba*) before a behavioural change was recorded. As any change in behaviour may have considerable impact upon the breeding or foraging success of a waterbird, it is important to monitor behavioural responses to human disturbance other than flight.

CAD's may be used as a measure of the sensitivity of a species to human disturbance, with most studies suggesting that seabirds allowing a closer approach suffer lower impacts as a result (for example Keller 1989, Burger and Gochfeld 1991, Dunlop 1996). However West *et al* (2002) and Fernandez-Juricic *et al* (2001) suggest that using CAD's in this way may not produce an accurate reflection of sensitivity as CAD's may vary considerably depending upon the stage of the breeding season, age and experience of the individual, degree of habituation, food availability and the number, behaviour and predictability of visitors to the colony area (Dunlop 1996, WBM Oceanics and Claridge 1997, Nisbet 2000, Dunlop and Rippey 2001, West *et al* 2002). It is noted that past research has to a large extent not investigated changes in seabird behaviour towards human disturbance over different stages of the breeding season (exceptions include Carney and Sydeman 1999, Nisbet 2000).

Rodgers and Smith (1995) report differences in the CAD of a breeding colony when approached on foot or via a boat. They found that most species allowed a much closer approach by humans over water (in boats) than over land (on foot). These findings have significant implications for the management of seabird breeding colonies on islands as a water-based approach may allow for better viewing opportunities for visitors and tourists and minimise disturbance to breeding colonies.

In studies similar to those mentioned above, approach or flushing distances are discussed in terms of increased tolerance and habituation (Cooke 1980, Burger and Gochfeld 1991, Burger and Gochfeld 1993, Lord *et al* 2001). Nisbet (2000) and Dunlop and Rippey (2001) state that habituation should be actively promoted by managers to reduce negative impacts and increase visitor education and interpretation through allowing a closer and more frequent and predictable approach regime. In contradiction, West *et al* (2002) state that frequent human activity may impact breeding seabirds more than infrequent activity.

In several studies, approach speed and noise levels are discussed, along with group size, clothing colour, frequency and predictability of disturbances (for example Kury and Gochfeld 1975, Anderson 1980, Burger and Gochfeld 1994, Gutzwiller and Marcum 1997, Carney and Sydeman 1999, Nisbet 2000, Dunlop and Rippey 2001, West *et al* 2002, Bolduc and Guillemette 2003, Thomas *et al* 2003). Most studies conclude that small groups cause less of a disturbance to breeding colonies than do larger groups (Burger and Gochfeld 1991, Lord *et al* 2001, Thomas *et al* 2003), although Kury and Gochfeld (1975) state that the number of people is unimportant in relation to the impacts of disturbance, as long as they stay in a tight group.

Burger and Gochfeld (1991) state that the type of approach can influence flushing distance. Burger (1981) found that joggers disturbed non-breeding waterbirds more often than walkers. Carney and Sydeman (1999) also agree that pace should be kept to a slow walk, whereas Lord *et al* (2001) found that speed had no effect on flushing distance. Few researchers have examined the effects of noise on flushing distance, however it is thought that loud noises can be a factor in causing disturbance to waterbirds (Giese 1997, Burger and Gochfeld 1998) and personal observation of Brown Noddies on Lancelin Island responding to thunder supports this theory.

Several reports suggest that visits to breeding colonies be made regularly, frequently and predictably with a short duration in order to reduce disturbance (Kury and Gochfeld 1975, Burger and Gochfeld 1994, Carney and Sydeman 1999, Nisbet 2000, Dunlop and Rippey 2001). Dunlop (1996) and WBM Oceanics and Claridge (1997) mention that fenced paths or boardwalks are an excellent way of encouraging predictable human behaviour. However Anderson (1980) and Blackmer *et al* (2004) recommend limiting the frequency of visits, while Bolduc and Guillemette (2003) found that frequency of visitation had no significant impact on Common Eider (*Somateria mollissima*) breeding success and West *et al* (2002) state that numerous disturbances to oystercatchers (*Haematopus ostralegus*) may be more damaging than fewer larger disturbances.

For management purposes, CAD's may be used to establish setback distances, or non-intrusive boundaries surrounding breeding colonies to reduce flushing caused by human disturbance or intrusion (Richardson and Miller 1997, Rodgers and Smith 1997, Fernandez-Juricic *et al* 2001) and thus reduce any negative impacts of mass up-flight (as previously discussed in Section 2.3). Such measures are important on small islands, as it is often difficult to keep the required distances between breeding colonies and visitors due to space restrictions.

To be effective, buffer zones (setback distances) should be based upon empirical data on wildlife responses to human disturbance (Richardson and Miller 1997). Rodgers and Smith (1995) recommend that setback distances (used to create buffer zones) for breeding waterbird colonies in Florida be estimated through use of a formula, (mean flushing distance +1.6495 SD of the flushing distance + 40 meters). Measurements of flushing distances from these colonies gave an average distance of 100 meters for wader colonies and 180 meters for mixed colonies.

Several studies have made recommendations to encourage establishing boundaries around breeding colonies or prohibiting access during early stages of the breeding season (for example Anderson 1980, Anderson 1988, Rodgers and Smith 1995, Richardson and Miller 1997, Giese 1998, Lord *et al* 2001, Bolduc and Guillemette 2003, Thomas *et al* 2003). WBM Oceanics and Claridge (1997) recommends temporary closures of parts of islands when sensitive species are nesting, while Ikuta and Blumstein (2003) found that protective barriers allowed birds to behave more naturally than those exposed to humans without a barrier. This type of zoning over space and time is designed to reduce visitor impacts by physically reducing the number of visitors in any once place at any one time (Budowski 1976, Newsome *et al* 2002).

Based upon the recommendations from the majority of research, the management of breeding seabird colonies should include the restriction of the numbers of visitors at one time, keep noise to a minimum and encourage visitors to remain on paths and walkways. The promotion of regular, frequent visits to seabird breeding colonies would depend upon whether habituation is possible in that species and desired by land managers. Timing of visits may need to be addressed, with more sensitive species being visited only later in the breeding season to avoid site abandonment and increased predation.

Knowledge of CAD’s has an important role in management of seabird breeding colonies on islands. Along with the above recommendations, establishing setback distances around sensitive colonies has been recommended to reduce negative impacts and promote habituation in several species (for example Rodgers and Smith 1995, Richardson and Miller 1997, Rodgers and Smith 1997). However because CAD’s vary between species, stages of the breeding season and often between geographic locations or populations (Erwin 1989, Carney and Sydeman 1999, Nisbet 2000, Blumstein *et al* 2003).

Management decisions thus should be geared towards site-specific circumstances and based upon a knowledge and understanding of the species and types and characteristics of visitors involved. Even within the one species it is often not possible to generalize about control measures for a particular activity or location (WBM Oceanics and Claridge 1997). Therefore, generic management recommendations can be dangerous and should be used only as a guide.

2.5.1 Relevance to Western Australia

South-western Australia's islands are an important component of the State's tourism industry, prized for their natural beauty, their close proximity to the mainland and the range of water-based recreational activities available (Western Australian Tourism Commission website 2002). Islands such as Penguin Island, Rottnest Island and Lancelin Island are becoming increasingly popular as tourist destinations, with peak visitation often coinciding with the breeding season of many species of seabird.

The management plans that cover these islands state that visitor-seabird interactions and the often-negative impacts that can result, are of significant concern (CALM 1995, CALM 2001, RIA 1997). Some of the main issues include: trampling of nesting seabirds, colony desertion as a result of human disturbance, managing visitor behaviour (through education, signage and walkways), access restrictions, possibility for commercial tourism and high silver gull (*Larus novaehollandiae*) numbers due to food provisioning by humans (CALM 1992, CALM 1995, CALM 2001, RIA 1997).

There is a lack of data on CAD's of seabirds in Western Australia with Dunlop (1996) being the only published work on the subject. Even Australia-wide there are few relevant published studies (examples include WBM Oceanics and Claridge 1997, Blumstein *et al* 2003). In its draft management plan for the Turquoise Coast (CALM 2001), CALM has made recommendations that the CAD's for seabirds breeding on these islands be investigated, as new proposals to land groups of tourists on the islands such as Lancelin Island are being considered. Similarly, several islands within the Abrolhos Archipelago have been marked for tourism developments (for example Long Island within the Wallabi Group).

A common problem on Lancelin Island and to a lesser extent on Rottnest Island is disturbance of beach nesting and sensitive seabirds such as Fairy Terns (*Sterna nereis*). Visitor related disturbances cause the continual failure of Fairy Terns nesting attempts during the summer months, when the island receives its peak visitation, even when management actions are taken to separate visitors from the nesting colony (Nic Dunlop pers comm).

Pelicans on Penguin Island generally breed throughout the year (with the exception of 2003, Nic Dunlop pers comm). While they are reasonably safe from human disturbance during the winter months when the island is closed, island staff and rangers maintain that those nesting on the northern end are often disturbed during the busy summer season. How much of an effect this has on their breeding success is not known, nor is the extent to which they have become habituated to human approach.

Many seabirds (such as Crested Terns) use the inaccessible islets or the islands within the lake complex on Rottnest Island to breed. How much of the traditional breeding grounds of these species have been lost to human disturbance is not known. However there have been seven known bird migrations and breeding relocations as a direct result of human disturbance during the island's recent history. While the authority does not make reference to the issue of human-seabird interactions in its latest management plan (RIA 2003), staff on the island are very aware of this issue and treat express concern.

There is therefore much need and scope for knowing and applying CAD information to the management of visitation to seabird breeding islands off the coast of WA. This work is important due to the increasing numbers of visitors to the islands, the possibility of future and increased access for commercial tourism operators and the ecological and conservation significance of many of the resident seabird breeding populations.

2.6 Conclusion

Interactions between humans and breeding seabirds occur frequently on islands and coastlines worldwide and are becoming more problematic due to increasing coastal development and visitation (WBM Oceanics and Claridge 1997, Newsome *et al* 2002). Many interactions between humans and breeding seabirds are in no way detrimental to the survival or reproductive viability of breeding colonies (Nisbet 2000). However there are some human activities that constitute a disturbance to breeding colonial seabirds, causing a change in their behaviour and/or physiology. These types of activities appear to be predominantly high intensity, large group activities but often include more passive activities such as nature observation and picnicking, and may impact upon a colony in a number of ways (Diamond 1985, Hockin *et al* 1992, Carney and Sydemen 1999). Commonly reported impacts include an increase in predation or exposure of eggs and young to the weather, increased stress levels and energy usage, reduced time available to adequately provision young and nest site desertion (for example Giese 1995, Carney and Sydeman 1999, Lord *et al* 2001, Burger 2003).

Whether habituation to human approach exacerbates or relieves these impacts is a topic of some contention amongst scientists and land managers. Several studies caution the idea that reduced response to human approach indicates reduced impact (WBM Oceanics and Claridge 1997, Gill *et al* 2001, Burger 2003). Others support natural habituation as a management tool to reduce negative impacts and allow closer approach by visitors (Nisbet 2000, Dunlop 2002). Clearly, there is a need for further studies investigating the positive and negative impacts of habituation for different seabird species under different conditions. Additionally, long-term monitoring should be used to determine the extent of any related negative effects resulting from this increase in tolerance.

It has been previously stated that the extent of human disturbance to seabird breeding colonies can be assessed through recording behavioural changes or by measuring the changes in reproductive success of a population exposed to disturbance (see section 2.5). Both methods are useful in obtaining an indication of the impacts human disturbance has on a breeding colony, however to quantify these in terms of lifetime reproductive output of the colony, a measure of breeding success over time should be used. However the data required for an accurate measure of the changes in reproductive output are beyond the scope of many studies. Therefore behavioural observations can often be the most practical method for measuring the effects of human disturbance to seabird breeding colonies and results may be extrapolated to give an indication of impacts and their effects on breeding success.

Critical Approach Distances (CAD’s) can also be estimated through observing and recording seabird behaviour. CAD’s are useful for managing high visitation levels to small islands as they ensure the required distance is allowed between humans and breeding seabirds to avoid disturbance and its associated impacts through the establishment of buffer zones or setback distances (Rodgers and Smith 1997). However CAD's vary between species and are influenced by many factors, some being the seasonality of disturbance, geographic location and the habituation of seabirds to human activities (for example Cooke 1980, Dunlop 1996, Nisbet 2000). It is therefore critically important that management decisions involving the deliberate use of habituation and CAD's of seabird colonies be made with site and species-specific information.

In Western Australia, CAD information has the potential to be used in planning and managing human-seabird interactions in some of the most rapidly growing areas in terms of tourism and recreation. Currently there is very little data relevant to Western Australian species. It is therefore recommended that these studies be undertaken in order to adequately manage human-seabird interactions on islands off our coastline.

3. STUDY AREA AND SPECIES OF INTEREST

3.1 Introduction

There are more than 200 islands larger than 10ha off the Western Australian coastline (Saunders and de Rebeira 1993) and many are vested as A-Class Nature Reserves with the primary objective of conservation and preservation of native flora and fauna (CALM 2001). In Western Australia, island visitation is increasing rapidly (Newsome *et al* 2002, WATC website 2003) and includes both private recreational visits (for example on Lancelin and Wedge Islands) and organised commercial tourism (for example on Penguin and Rottnest Islands).

Lancelin, Rottnest and Penguin Islands (see Figure 3.1) are the focus of this study as they represent a range in size, location, conservation value, breeding seabird species, visitation regimes and issues related to the management of visitors and their interactions with breeding seabirds (see Table 3.1). The primary reasons people visit Penguin and Lancelin Islands include: swimming, fishing, boating, diving and exploring (CALM 1992, Revitt and Sanders 2002), while Rottnest Island visitors experience many of the same activities as well as dining out and overnight stays (RIA 2003).

The breeding seabirds that inhabit these islands include the Australian Pelican (*Pelecanus conspicillatus*) on Penguin Island, Brown Noddies (*Anous stolidus*) at Lancelin Island and Crested Terns (*Sterna bergii*) on Rottnest Island (Figure 3.1). These breeding populations have been identified as being sensitive to human disturbance, and/or ecologically significant for their geographic location and conservation value.

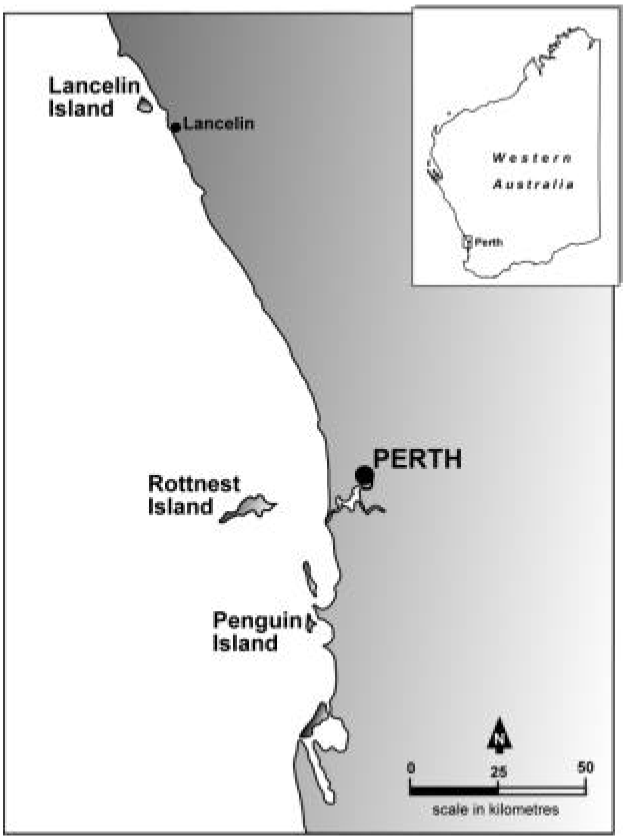

Figure 3.1*- map showing the locations of the three focal islands.*

In summary, this section will provide an overview of the three focal islands of Rottnest, Lancelin and Penguin, to gain an understanding of visitor numbers, the current management arrangements, the seabirds that use these islands as breeding grounds and the specific species of interest.

Table 3.1- *Summary of the three study islands. (Sources from CALM 1995, CALM 2001, RIA 2003, Nic Dunlop pers comm)*

ISLAND	**VESTING AND MANAGEMENT**	**VISITOR NUMBERS**	**BREEDING SEABIRDS**
Penguin Island	C-Class Reserve. Managed by the Department of Conservation and Land Management in accordance with the *Conservation and Land Management Act 1984*	Approximately 80,000 visitors per year on commercial vessels alone. Many visitors additionally travel across by private vessel or use the sandbar, however exact numbers are not known.	**Gulls and Terns** Silver Gull (*Larus novaehollandiae*) Bridled Tern (*Sterna anaethetus*) **Pelicaniformes** Australian Pelican (*Pelecanus conspicillatus*) Pied Cormorant (*Phalacrocorox varius*) Little Pied Cormorant (*Phalacrocorox melanoleucos*) **Petrels and Shearwaters** Little Shearwater (*Puffinus assimilis*) **Other** Little Penguin (*Eudyptula minor*)
Rottnest Island Nature Reserve	A-Class Reserve gazetted for public recreation. Managed by and vested in the Rottnest Island Authority in accordance with the *Rottnest Island Authority Act 1987*	Approximately 500,000 visitors per year visit Rottnest Island. This includes 350,000 that travel by commercial ferry or aircraft. Occupancy is seasonal, with December- March being the peak months.	**Gulls and Terns** Silver Gull (*Larus novaehollandiae*) Bridled Tern (*Sterna anaethetus*) Caspian Tern (*Sterna caspia*) Crested Tern (*Sterna bergii*) Fairy Tern (*Sterna nereis*) **Pelicaniformes** Pied Cormorant (*Phalacrocorox varius*) Little Pied Cormorant (*Phalacrocorox melanoleucos*) **Petrels and Shearwaters** Wedge-tailed Shearwater (*Puffinus pacificus*) **Other** Osprey (*Pandion haliaetus*) Pied Oystercatcher (*Haematopus longirostris*)

Lancelin Island	A-Class Nature Reserve Managed by the Department of Conservation and Land Management in accordance with the *Conservation and Land Management Act 1984*	Visitor numbers are largely unknown, however it is thought that up to 150 people can be present on the island during the summer holidays (Nic Dunlop pers comm.). The majority of these visitors use private boats.	**Gulls and Terns** Pacific Gull (*Larus pacificus*) Silver Gull (*Larus novaehollandiae*) Bridled Tern (*Sterna anaethetus*) Caspian Tern (*Sterna caspia*) Common Noddy (*Sterna stolidus*) Crested Tern (*Sterna bergii*) Fairy Tern (*Sterna nereis*) Roseate Tern (*Sterna dougallii*) Sooty Tern (*Sterna fuscata*) **Pelicaniformes** Pied Cormorant (*Phalacrocorox varius*) **Petrels and Shearwaters** White-faced Storm-petrel (*Pelagodroma marina*) Wedge-tailed Shearwater (*Puffinus pacificus*) **Other** Osprey (*Pandion haliaetus*) Pied Oystercatcher (*Haematopus longirostris*)

3.2 *Physical Overview*

Most of the islands off the coast of Western Australia were formed approximately 10,000 years ago due to glaciation and deglaciation events causing the sea level to rise and then fall (CALM 2001). While the sea level was at its lowest, wind erosion of the continental shelf formed extensive parallel sand dunes, which over time hardened into limestone structures. Once the sea level rose to its current height, the highest limestone dunes became the islands and emergent rocks that dot the Western Australian coastline from Cape Bouvard to Dongara (Dunlop and Rippey 2001).

While all three islands experience a Mediterranean climate, there is an appreciable difference in rainfall between Penguin Island, which receives approximately 881mm per year and Lancelin Island at 628mm per year (Dunlop and Rippey 2001).

A unique aspect of the northern part of the Western Australian coastline is the Leeuwin Current. The Leeuwin Current brings warm water down the coast from the equator to the Great Australian Bight (CALM 2001). Flowing in the opposite direction is the cooler Capes Current. The Capes Current flows strongest during the summer months and provides marine species and visiting breeding seabird colonies with cold nutrient-rich up-wellings in which to feed (CALM 2001). It is thought that the Leeuwin Current is responsible for the slow spread of predominantly tropical seabird species such as Bridled Terns (*Sterna anaethetus*) and Brown Noddies into more southerly islands by dispersing tropical marine biota (including prey species) to higher latitudes (Dunlop and Rippey 2001).

3.3 Penguin Island

3.3.1 Location, management and vesting

Penguin Island (Figure 3.2) is situated in the Shoalwater Islands Marine Park at approximately 32° 18’ 30” S, 115° 41’ 15” E and has an area of 12.5ha (CALM 1992, Crane *et al* 1995). The Marine Park was reserved in 1990 as an A-Class nature reserve with the primary focus of the preservation and conservation of flora and fauna (CALM 1992). The park is currently vested with the National Parks and Nature Conservation Authority (NPNCA) and managed by the Department of Conservation and Land Management (CALM) under the *Conservation and Land Management Act*

1984. Penguin Island itself is vested as a "Conservation Park" or C-Class reserve (CALM 1992). This incorporates conservation, research and preservation of historic features, as well as a higher level of visitation than anticipated in A-Class reserves (CALM 1992).

Figure 3.2- *Penguin Island looking in the direction of the northern Pelican colony (photo by Melanie Barter)*

CALM has been managing Penguin Island since 1987 and has progressively undertaken works to protect the natural environment and provide facilities to the public (Crane *et al* 1995). The main management concern for Penguin Island is wildlife interactions with humans, as stated in the *'Shoalwater Islands Marine Park Draft Management Plan 1995'* (CALM 1995). The *'Shoalwater Islands Management Plan 1992-2002'* also states that human pressures have affected the island's environmental values and degraded the quality of the recreational experience for many visitors (CALM 1992).

On busy summer days, CALM (1992) has recorded that there can be more than 3,500 people visiting the island within a day and this figure is likely to have risen in recent years (Terry Goodlich pers comm). As a consequence of the increasing numbers of visitors to the island, CALM has, since the early 1980's introduced site hardening and the constant presence of a ranger during peak visiting times (CALM 1992, Nic Dunlop pers comm). Today, visitor access on the island is restricted to boardwalks and the beaches while signage is used to direct access away from seasonally sensitive areas such as the Australian Pelican breeding colonies.

3.3.2 Visitor profile

Penguin Island currently receives approximately 80,000 visitors each year (Louisa Liddicoat pers comm). People cross to the island via 'Penguin and Seal Island Cruises', the only licensed operator to land visitors on the island. However this number does not include those that walk over the sandbar or use their own boats to reach the island. Consequently, the actual number of visitors may in reality be much higher (Louisa Liddicoat pers comm).

Visitors to Penguin Island are all day-trippers, as there are no accommodation facilities on the island, except small quarters for the ranger and researchers. Popular visitor activities include: recreational fishing, diving, wildlife observation, picnicking and walking (CALM 1995). Another popular attraction is the 'Penguin Experience Visitor's Centre', which provides interpretive information on the breeding colony of Little Penguins (*Eudyptula minor*). The Centre holds daily feeding displays and satisfies the desire of the public to see penguins without causing environmental degradation or stress to non-captive penguins by negating the desire for visitors to search for wild penguins.

3.3.3 Breeding seabirds

There are several species of breeding seabird on Penguin Island. Of these, only the Little Shearwater (*Puffinus assimilis*) is listed by WBM Oceanics and Claridge (1997) as being of 'special concern', an unofficial category of threat status that describes species that are not threatened or rare, but whose populations are small or declining. Since boardwalks were constructed on Penguin Island and the reminder of the vegetated area established as 'off-limits' to visitors, the number of breeding seabird species has increased, with the most recent additions being Little Pied Cormorants (*Phalacrocorox melanoleucos*), Pied Cormorants (*Phalacrocorox varius)* and Australian Pelicans (Nic Dunlop pers comm).

In the early 1980's the population of Bridled Terns numbered several pairs. Today, the colony of Bridled Terns on Penguin Island covers 100% of the available area and number in their thousands (Dunlop 1996). However there have also been several breeding species lost from Penguin Island due to increasing human activity, including Caspian Terns, Greater Crested Terns and the Sooty Oystercatcher (*Haematopus fuliginosus*) (Nic Dunlop pers comm), emphasizing the relative sensitivity of these species to human disturbance.

3.3.4 Species of interest- the Australian Pelican (*Pelecanus conspicillatus*)

Figure 3.3- *Australian Pelicans on Penguin Island*

Penguin Island is the location of one of the few known breeding colonies of Australian Pelican on Western Australia's coastline (CALM Naturebase Website 2002). While this in itself is significant for conservation, Johnsgard (1993) states that the Western Australian population of *Pelicanus conspicillatus* can be questionably separated as a sub-species, *westralis.*

The Australian Pelican is a relatively new arrival to Penguin Island, apparently having been displaced from the Peel Estuary after a low-flying light plane panicked the colony (Nic Dunlop, pers comm). They have since moved from their preferred breeding area in the Peel Estuary to Seal Island in Shoalwater Bay and then on to the north end of Penguin Island, (Figure 3.4) where they have remained since 1998, (CALM Naturebase Website 2002, Nic Dunlop, pers comm).

This species typically breeds on bare ground or in low, patchy vegetation and has great variation in their breeding season, depending upon food availability (Johnsgard

1993). Previous to 2003, the Penguin Island northern breeding colony was generally active all year and typically consisted of crèches with young of varying age. However between March and July 2003 this area was found to be abandoned (pers obs 2003). In July 2003, a breeding colony of approximately 60 pairs settled for the first time on the southern end of the island and three weeks later a similar number began using the northern colony (pers obs 2003).

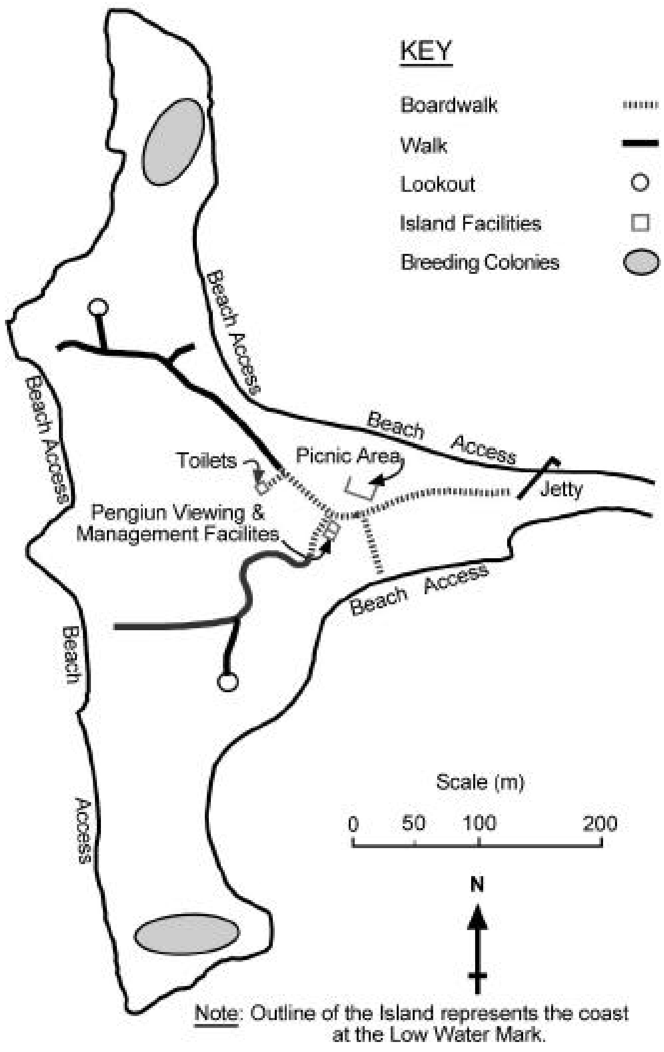

Figure 3.4- Penguin Island showing the approximate locations of the two Australian Pelican breeding colonies.

Pelicans have low site fidelity (see Figure 2.2) and therefore will sometimes abandon a breeding site if disturbed early in their breeding season (Johnsgard 1993). For this reason they are thought to be particularly sensitive to human disturbance (Anderson and Keith 1980, Carney and Sydeman 1999).

Previous studies on human disturbance to breeding Brown Pelicans (*Pelecanus occidentalis*) have reported a range in their Critical Approach Distances (CAD's) of between 600m in a study by Anderson (1988) to 100m (Rodgers and Smith 1995) without causing flushing. A study involving roosting Australian Pelicans at Botany Bay, NSW revealed that they could be approached to a distance between 20m and 60m (Blumstein *et al* 2003). Past observations of the Pelicans on Penguin Island have revealed that they are often approached by fishermen, surfers or tourists to within 100m without flushing occurring.

The Australian Pelican was chosen as a subject of this research due to reports of severe sensitivity to human disturbance in other Pelican species, and the ecological and conservation importance of the Penguin Island population. Additionally, this species has not be studied in any detail in Australia, with Blumstein *et al* (2003) potentially being the only published research on approach distances for this species.

It is important to gain an understanding of the behavioural responses and CAD's of the Australian Pelican on Penguin Island for several reasons. Firstly, as this island is highly visited, useful data on habituation and tolerance of this species may be obtained. Secondly, management recommendations for a highly disturbed colony may be useful to managers dealing with the same species elsewhere, and thirdly it is important to ensure that no negative behavioural changes are in fact occurring as a result of the current visitation regime and boardwalk placement, as this may lead to further disturbance or displacement of this colony.

3.4 Lancelin Island

3.4.1 Location, management and vesting

Lancelin Island (Figure 3.5) is part of the Turquoise Coast Island system of 38 islands gazetted between 1958-1968 (CALM 2001). It is located at 31° 00’ 30” S, 115° 18’ 55” E, has an area of 8.2ha and is an A-Class Nature Reserve vested with the NPNCA and managed by CALM (CALM 2001). It is located approximately 110kms north of Perth and 800m off the coast of Lancelin townsite (see Figure 3.1). Until recently the primary management concern on Lancelin Island was unrestricted access and its effects on the native flora and breeding seabirds on the island (CALM 2001). To remedy this, a walkway was added through the middle of the northern tip, restricting access to this walkway and the two beaches on the east and west sides of the island, thus minimising visitor impacts on the fragile vegetation and breeding seabirds (Nic Dunlop pers comm).

More recently, the primary management concern is related to visitor numbers and the often-disruptive activities that they engage in. Visitation to the islands of the Turquoise Coast group is predicted to increase with the planning of the northern coastal road from Perth to the mid-west (CALM 2001) and this growth in tourism numbers and accessibility is likely to lead to a greater disruption to the breeding seabird colonies (WBM Oceanics and Claridge 1997).

Figure 3.5- *Lancelin Island (photo by Nic Dunlop)*

3.4.2 Visitor profile

Lancelin Island is easily accessible by boat from the mainland and is popular for recreational activities such as swimming, walking, bird watching, fishing and nature appreciation (CALM 2001, Revitt and Sanders 2002). Access is restricted to the daytime and there are no accommodation facilities on the island.

Lancelin Island currently does not have an organised tourism regime and visitor numbers are largely unknown (CALM 2001) although it is thought that up to 150 people may visit the island at any one time during the summer holidays (Nic Dunlop pers comm). Because of this growing popularity among residents and the prospect of further growth in tourism, commercial operators are expressing an interest in landing groups of people on the island (CALM 2001).

3.4.3 Breeding seabirds

Lancelin Island is host to at least 18 different species of seabird that use the island to breed, predominantly over the summer months (CALM 2001). Of these, several are considered to be particularly sensitive to human disturbance and can suffer severe negative effects from uncontrolled visitor access. (For example: Crested Terns, Fairy Terns, Caspian Terns and Pacific Gulls).

The seabirds that nest on this island are a mixture of temperate and tropical species. The southward movement of the tropical species is attributed to the Leeuwin Current, allowing a southerly shift in prey abundance and distribution (Dunlop and Rippey 2001). Species such as the Brown Noddy have recently moved southward from north-western Western Australia and the equator to take advantage of these changes (Dunlop and Rippey 2001).

3.4.4 Species of interest- the Brown Noddy (*Anous stolidus*)

The Brown Noddy (a tropical seabird) was first detected on Lancelin Island in 1992 as a colony of five pairs. Now the island is host to over 960 breeding pairs (Dunlop and Mitchell 2001). The Brown Noddy additionally nests in several northern locations throughout Australia and is common throughout the tropics of the world (Croxall *et al* 1984). The population at Lancelin Island is ecologically important as it is the southern-most known population of this species in the world and therefore has considerable conservation and research significance.

Figure 3.6- *Brown Noddy on Lancelin Island (photo by Peter Mortimer)*

This species nest on low bushes (for example nitre bushes (*nitraria billardierii*)) in dense colonies and their nests are cryptic to aid in predator evasion (see Figure 2.2). Their breeding season on Lancelin Is. is between October and February. Incubation is typically 35 days and the chicks are able to fly after 6 weeks (Nic Dunlop pers comm). Reproductive maturity is reached at an approximate age of three (Dunlop and Rippey 2001).

Figure 3.7 shows the approximate breeding location of this species, as they return to the same breeding site each year.

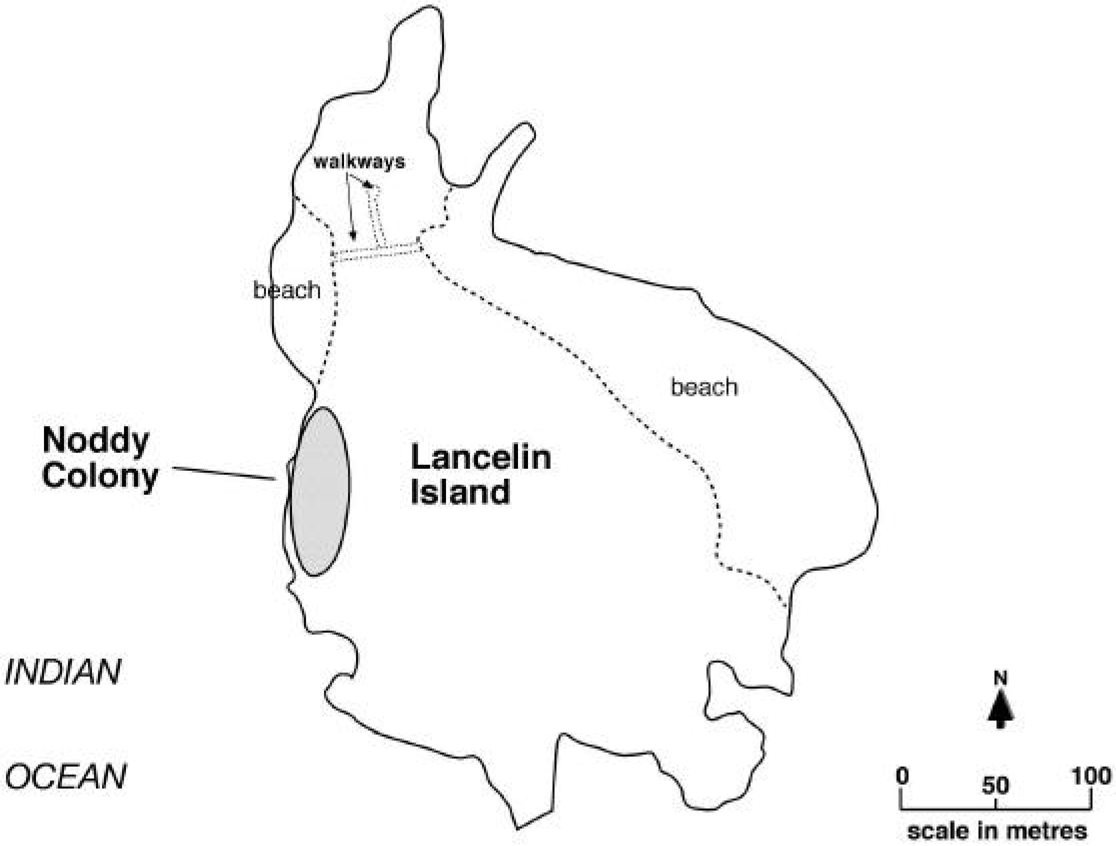

Figure 3.7- *Approximate location of the Brown Noddy nesting colony on Lancelin Island*

There has been no work done on Brown Noddies in terms of CAD's, although observation suggests that they allow close human approach on Lancelin Island, particularly later within their breeding cycle (Nic Dunlop pers comm). Anecdotal evidence suggests that this population has habituated to researcher interference, as populations of this species in the Abrolhos Archipelago react at a much larger distance (Nic Dunlop pers comm). This population's significance for research into climate change and species shifts in distribution makes it particularly important to limit human interference.

3.5 Rottnest Island

3.5.1 Location, management and vesting

Rottnest Island (32° 00'S, 115° 30'E) is located approximately 18kms off the Western Australian coastline and is approximately 1900ha in area (Saunders and de Rebeira 1985a, Saunders and de Rebeira 1993, see Figure 3.1). It was declared an A-Class Nature Reserve in 1917 under the *Permanent Reserve Act 1899* (RIA 2003). At the same time the 'Rottnest Board of Control' was formed and charged with the management of the island. Today, Rottnest Island is used predominantly for public recreation and is managed by the Rottnest Island Authority (RIA) under the *Rottnest Island Authority Act 1987* (RIA 2003).

Rottnest is unique amongst Western Australian islands, in that is the only one that possesses a salt lake complex (Saunders and de Rebeira 1993). They were formed when a cave system collapsed and filled with seawater. Now, three deep lakes and four shallow saline lakes exist as a system separate to the sea (Saunders and de Rebeira 1993).

Compared with Lancelin and Penguin Islands, Rottnest Island is larger, has significantly more infrastructure, with a township, bitumen roads leading to the west side of the island and has a long history of colonization. There has consequently been pronounced changes to the natural environment through logging, draining of lakes and early disposal of rubbish (Saunders and de Rebeira 1986, RIA 2003).

The *Rottnest Island Management Plan 1997-2002* states that human-wildlife interactions are of concern, and recommends that access should be restricted to important bird breeding colonies to reduce the impact human disturbance has on these populations. Additionally, the *Rottnest Island Management Plan 2003-2008* states that 3 past extinctions and seven site desertions of various terrestrial and water bird species on the island have been a direct result of human disturbance. However this plan, (2003-2008) draws no attention to the current issue nor makes any recommendations for management.

3.5.2 Visitor profile

The Rottnest Island Authority (RIA) estimates that up to 500,000 people visit Rottnest Is. each year by either private or commercial vessel, and visitor numbers are steadily rising (RIA 2003). Visitors consist of day-trippers and overnighters and in contrast with Penguin and Lancelin Islands, there is a wide range of accommodation facilities on the island, ranging from a camping ground to several hotels and apartments (RIA 2003, pers obs). October to May is the busiest period, with some days recording “very high numbers of visitors” (pp 63, RIA 2003) although an actual estimated figure is not stated.

It has been reported by the Rottnest Island Authority (2003) that visitor activities and behaviour can have an influence on the degree of impact caused to the natural environment. There is however limited data available on visitor usage patterns and behaviours although it is thought that visitors enjoy walking and bike riding on designated pathways and roads, organised tours, boating, recreational fishing and snorkelling (RIA 1997).

3.5.3 Breeding seabirds

The bird-life of Rottnest Island has been studied since 1904, with the research of more recent years providing the most information (Saunders and de Rebeira 1985a). However this research mainly concerns shorebirds and waders, while many of the seabirds that visit this island to breed have not been examined in any great detail.

3.5.4 Species of interest- the Greater Crested Tern (*Sterna bergii*)

Figure 3.8- *Crested Terns nesting on Herschell Istet (photo by Melanie Barter)*

Crested Terns (Figure 3.8) are one of the most common tern species on the west coast of Australia (Crane *et al* 1995). An estimated 1500 pairs nest on small offshore islands around the coastline of metropolitan Perth (Crane *et at* 1995). There are both autumn and spring breeding populations of Crested Terns. When one population is reproductively active (nuptially plumaged) the other is inactive (eclipse plumaged) (Dunlop 1986, Dunlop and Rippey 2001). Crested Terns typically nest on simple scrapes on the ground between rocky outcrops and island vegetation and in tightly packed colonies (Saunders and de Rebeira 1985a).

Crested Terns move around a broad natal breeding range, laying in different sites each year and synchronise their breeding through pre-laying behaviours such as mass flight and ‘clubbing’ together near nesting areas (Dunlop 1986). These are forms of anti-predator behaviour, additionally displayed by several other seabird species, such as Pied Cormorants, Caspian Terns and Fairy Terns. Often this species will nest on the southern point of Lancelin Island, and on the islets in West Baghdad and Herschell Lakes on Rottnest Island. During the 2003/2004 breeding season they bred on the islet in Lake Herschell (Figure 3.9).

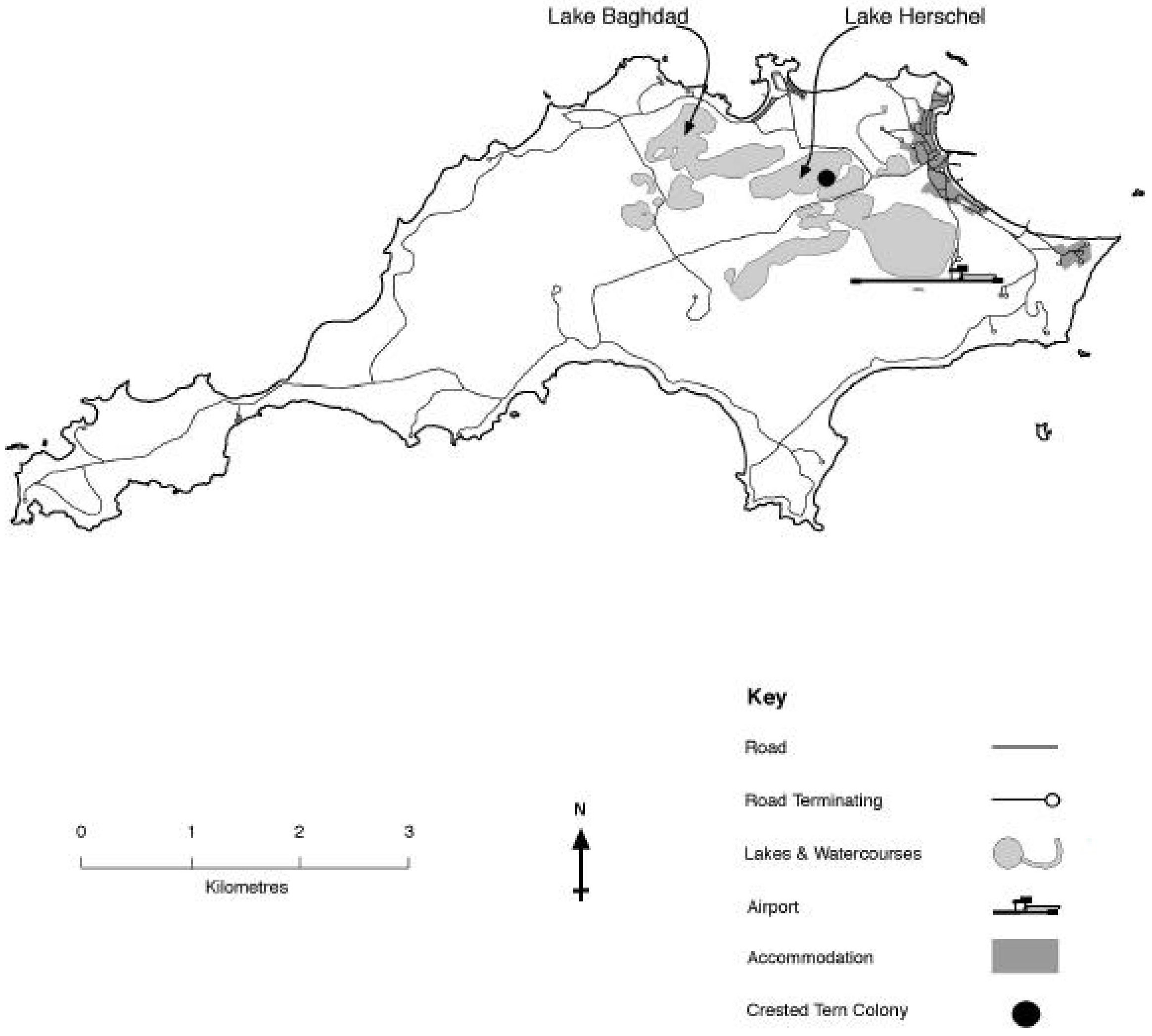

Figure 3.9- *The approximate locations of the Crested Tern breeding colony in Herschell Lake, Rottnest Island*

Crested Terns are thought to be highly sensitive to human disturbance (Dunlop and Rippey 2001). This is because they will often desert nesting sites, particularly early within their breeding cycle, even when disturbed by a natural predator. Human disturbance can have consequences for the breeding populations of Crested Terns, as they will often not re-lay after disturbance while replacement clutches may be smaller and less viable (Dunlop 1987, Burger and Gochfeld 1994). It is for these reasons that this species was chosen as a subject for this research.

4. **METHODOLOGY**

4.1 Introduction

Several studies have put forward various methods to determine the Critical Approach Distances (CAD's) of breeding or feeding waterbirds (for example Rodgers and Smith 1995, Giese 1998, Fernandez-Juricic *et al* 2001, Bolduc and Guillemette 2003). An experimental method is the measured approach of a person as they walk towards a breeding colony and the synchronous recording of behavioural responses.

In this study, an approach-retreat sequence protocol was utilised on a range of colonies of three species of seabird; the Australian Pelican (*Pelecanus conspicillatus),* the Greater Crested Tern (*Sterna bergii*) and the Brown Noddy (*Anous stolidus*). The observations were made on three islands off the coast of Western Australia, Penguin, Lake Herschell (Rottnest) and Lancelin Islands. This experimental investigation of the responses of breeding seabirds to human intruders tested the following variables.

- Species with different reported levels of tolerance
- Phase of the breeding cycle (nest-building or early and late incubation)
- Effect on behaviour of previous exposures

Table 4.1- *Summary of sites, species involved and experimental design*

		No. of APPROACHES		
ISLAND	SPECIES (Common name)	NEST BUILDING	EARLY INCUBATION (<1 week on eggs)	LATE INCUBATION (>3 weeks on eggs)
Lancelin	Brown Noddies	12	13	
Rottnest	Crested Terns		9	13
Penguin	Australian Pelicans		20	24

More specifically, the project methodology consisted of three parts:

1. The approach-retreat sequence and the recording of seabird behaviour
2. The analysis and comparison of the results between variables, and
3. The use of this information to determine CAD's, setback distances and the recommendation of general management guidelines.

This study was conducted with permits issued under Regulations 4 & 17 of the Wildlife Conservation Act 1950, the Murdoch University Animal Ethics Committee Regulations and with permission from the Rottnest Island Authority.

4.2 The Neutral Profile (Control)

Neutral behaviour was observed and recorded for at least 20 minutes before the start of a day's approaches and for an equal amount of time after experimentation had ceased for the day (Appendix 2). This was done for two reasons:

1) As a baseline from which disturbed behavioural signals could be distinguished from neutral behaviour, and
2) As a control with which to compare disturbed behaviours to make sure that neutral levels had been reached before the start of the next approach.

Statistical comparison of behavioural frequencies between neutral and disturbed profiles was carried out to determine significantly different behaviours, which were then used as behavioural signals indicating disturbance.

4.3 Recording Behavioural Profiles

Behaviour was recorded by the observer as a series of events, which were later grouped under the following categories: vigilance, aggression, intention movements, displacement and relaxed (neutral/ undisturbed) behaviour. Behavioural types were classified based upon their differences in frequency of occurrence to neutral behaviour and at what stage during the approach-retreat sequence they occurred (ie: before, during or after the approach). Terminology describing behaviours and postures can be found in Manning (1972), Altmann (1974), Henson and Grant (1991) and Johnsgard (1993).

Behavioural profiles were recorded for all three species during neutral (undisturbed) conditions (the control), during stimulation (an approach) and during relaxation (the period immediately after the approach). The time taken for behaviour to transition from stimulated back to neutral levels (relaxation time) and the time taken to return to the nest site if flushing occurred (return time) were also recorded.

The purpose of recording neutral behaviour was to provide a control with which to compare the other data sets and to determine the context of behaviours observed at a higher frequency during the stimulation or relaxation phases of the approach-retreat sequences. That is, in order to identify what constituted pre-flight or displacement behaviour. Neutral behaviour displayed by each species was observed for 20 minutes immediately prior to the onset of the first approach (Appendix 2). Target individuals were each observed for 2 minutes to incorporate variation in individual responses into the overall dataset.

A period of recovery time (15-25 minutes depending on the species/colony type) was left between approaches to ensure the birds returned to normal parenting behaviour. The time taken to return to neutral patterns of behaviour (relaxation time) was recorded. This was measured by assessing the frequency of displacement behaviours (such as preening and nest-building activity) with neutral/ undisturbed levels. The next approach started after neutral frequencies of behaviour had been observed for more than 5 minutes.

4.4 Experimental Design

Breeding colonies of Australian Pelicans, Crested Terns and Brown Noddies were exposed to a series of approach-retreat sequences that involved a human walking towards a pre-determined individual bird on the edge of the breeding colony (the *approacher*) and an *observer* recording the birds' behaviour during the approach. The design for the approach-retreat experiment was modelled upon studies made by Rodgers and Smith (1995), Giese (1998) and Lord *et al* (2001).

The object was to terminate the approach at the point where pre-flight intention movements were first observed. This was termed the Pre-flight Initiation Distance (PFD). In some cases, during the earliest approaches, flight or evasive behaviour was initiated, referred to as the Flight Initiation Distance (FID).

For all three species, 'focal animal sampling' (Altmann 1974) was used and target individuals were selected by firstly choosing an adult from the closest (to the *approacher*) edge of the colony. Targets were then selected in a clockwise manner around the near edge of the colony. In this way there was minimal chance of an individual being targeted more than once in a day, disturbance was minimised through choosing birds at the colony edge and variation in individual responses could be incorporated into the overall data set.

A pace of 1 meter every 2 seconds was selected for all approaches (Rodgers and Smith 1995, Giese 1998) to exclude pace as a variable and because Burger (1981) and

Carney and Sydeman (1999) suggest that a fast approach (ie: running or jogging) is more likely to cause mass up-flight amongst a colony than a walking speed.

Clothing colour was kept to browns, greens and black as bright colours are sometimes perceived as threatening or display signals to many seabird species (Gutzwiller and Marcum 1997). Additionally, it was ensured that the *approacher* was visible to the breeding colonies throughout the entire recorded approach.

4.4.1 Australian Pelicans and Greater Crested Terns

Two colonies of Australian Pelican were approached on Penguin Island, the southern during late incubation and the northern during early incubation. This was done to remove previous exposure as a variable between the two stages of breeding, as if the same birds had been approached early within the breeding season this would have likely affected the results when approached at a later stage.

Similarly, habituation between two phases of breeding in Crested Terns was minimal because of the synchronous breeding strategy of this species which involves the outwards growth of the colony over time as new pairs settle on the outskirts of the group. Therefore during late incubation, the birds that were approached were those that had not previously been exposed to this stimulus.

Behaviour indicating that up-flight was imminent (pre-flight behaviour) was utilized during approaches in preference to initiating up-flight in both Crested Terns and in Pelicans. For these species, experiments were run on adults in colonies that were in the early (< 1 week) or late (> 3 weeks) stages of incubation. The stage of incubation in Australian Pelicans and Crested Terns was gauged by observing when the first breeders arrived. Experiments were not carried out on colonies with chicks in order to prevent possible increases in the incidences of chick mortality through entanglement, drowning or predation and because chicks are soon mobile and move away to form crèches.

4.4.2 Brown Noddies

Methods used for Brown Noddies nesting on Lancelin Island were different due to their extremely high tolerance to human presence. It was therefore deemed useful to determine Noddy response to human approach in terms of the time spent away from the nest site after a disturbance.

Research was undertaken co-jointly with banding to reduce the overall impact upon the colony. No more than 10 approaches were carried out at any one time or on the same group of birds. Brown Noddies were tested during the nest building and incubation stages because of the low risk of site desertion and the difficulty in determining the stage of incubation in a mixed (non-synchronous) stage colony.

Movement away from the nest site was encouraged in the approaches to Brown Noddies after initial results suggested very high tolerance levels in this species at both stages of the breeding season. The *approacher* attempted once to extend a hand out towards an incubating Noddy to encourage movement from the nest. A record was made of whether this caused the individual to move from the nest or remain incubating.

4.4.3 Conducting the experiment

4.4.3.1 Setting the waypoint

The waypoint was set as the closest the *approacher* could advance towards the colony without causing en-masse disturbance during an initial approach (more than 50% of the colony responding by up-flight). This was set into a global positioning system (GPS) and then the *approacher* retreated along the same path at the pace of 1m/2secs. The distance between the waypoint and the actual edge of the colony was then estimated by the *observer* and the *approacher*. This procedure was necessary to minimise disturbance to breeding birds by not inducing flushing of the entire colony when setting the waypoint. However any error in this estimation was then consistent throughout all approaches for that species in that location (Figure 4.1).

4.4.3.2 Approaching and retreating

Prior to the first approach being initiated the normal behaviour of the breeding birds was observed and recorded for 15-20 minutes. Immediately afterwards, the approach-retreat sequence began, with the *observer* monitoring the approach progress and seabird behaviour through a telescope situated between 40-300 meters away from the colony, (the distance depended upon species tolerance) and communicating to the *approacher* via a two-way radio.

The *approacher* started from a preset distance away from the waypoint ranging from 20m-150m, depending upon the natural tolerance of the species and limitations in the terrain and line of sight. In each case the starting distance initiated no disturbed behavioural responses within the colony (ie: no change from neutral behaviour). The *approacher* walked slowly and in a straight line towards the nearest edge of the colony, measuring their own pace and distance from the preset waypoint using a GPS. The *approacher* relayed their progress to the *observer* in 10 meter increments, which the *observer* used in recording the behaviour of the target bird (see Appendix 1).

Once the observer noted pre-flight behaviour in the target or closely neighbouring birds, the *approacher* was told to stop, record their final distance from the waypoint and retreat along the same path at the same pace.

Figure 4.1 shows how behaviour was recorded in 10 meter intervals while the *approacher* advanced along the path to the pre-set waypoint. During later approaches, the *approacher* advanced past the waypoint and so was able to more accurately measure the distance between the waypoint and the colony edge using the GPS.

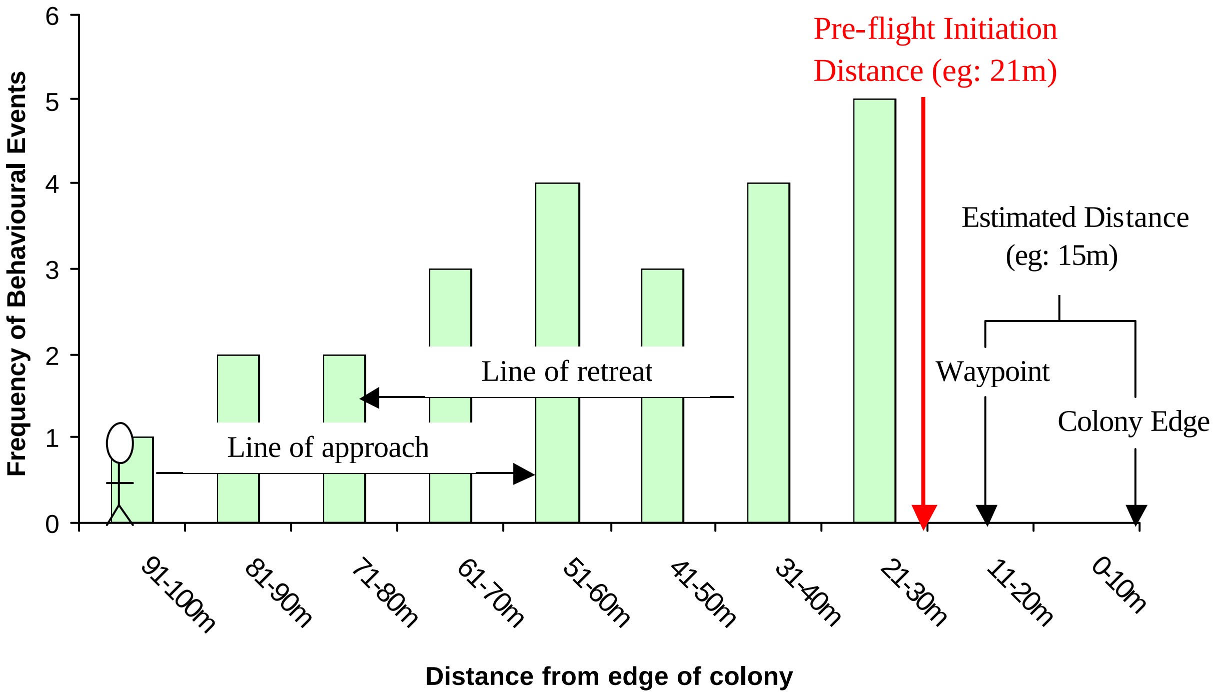

Figure 4.1- *Diagram showing an example of an approach-retreat sequence and the recording of behavioural events.*

5. RESULTS

5.1 Australian Pelicans (Pelecanus conspicillatus)

5.1.1 Introduction

Section 5.1 displays the results gathered from a total of 44 approaches which were made on two colonies of Australian Pelicans (*Pelecanus conspicillatus*) at two different phases of incubation on Penguin Island during August 2003. The northern colony was observed during early incubation (< 1 week) and the southern during a later stage of incubation (~ 1 month) (see Figure 3.4 for locations). Pelicans at the southern colony were observed for three days, with 8, 10 and 6 approaches being carried out on days 1, 2 and 3 respectively. The northern colony was observed over two days, with 10 approaches made each day.

This section firstly describes what behaviours were used to signal disturbance and how these were identified. It then goes on to examine the differences in pre-flight distances (PFD's), relaxation times and displacement behaviour between early (< 1 week) and late (~ 1 month) stages of incubation and how results show evidence of short-term habituation.

5.1.2 Australian Pelican behaviour in response to human approach

Observations of Pelican behaviour in the two colonies revealed that there was a difference in behavioural response to the appearance of an intruder between early and late incubation phases. Some of these signals are displayed in Figure 5.1.1 below.

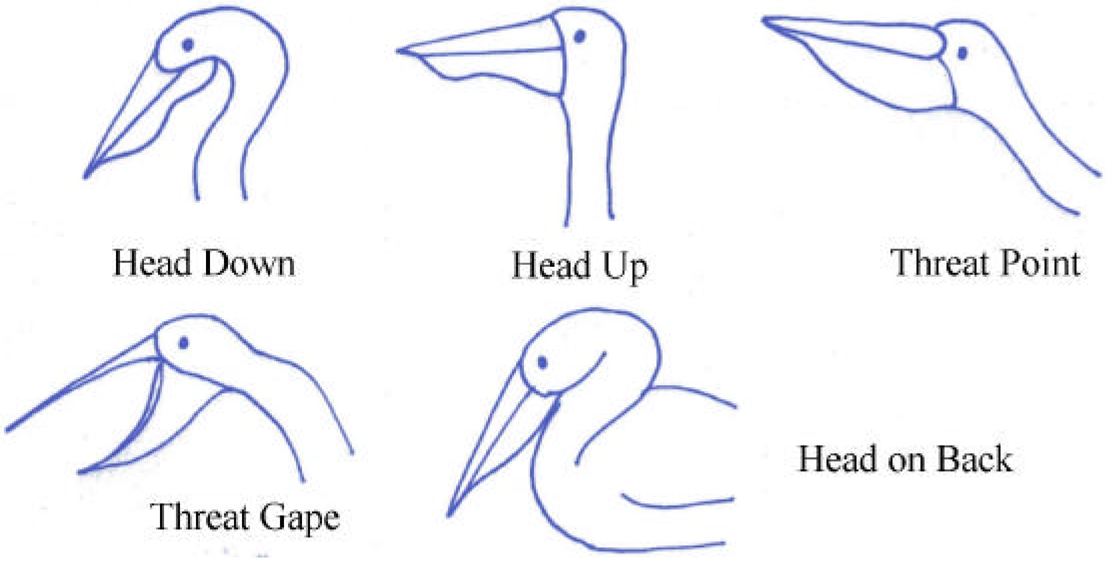

Figure 5.1.1*- Some of the recorded individual behaviours of Australian Pelicans on Penguin Island.*

Pelican behaviour was found to change in frequencies or proportions depending upon the closeness of the *approacher*. The behaviour of Pelicans that had been incubating for approximately 1 month is used as an example to illustrate this, as a very similar behavioural repertoire exists between the two stages of the breeding season.

5.1.2.1 Neutral profile

Neutral behaviour for nesting Pelicans typically consisted of the adult sitting on the nest in the 'head on back' or 'head under wing' position, with occasional preening, nest maintenance or shifting on the egg. In both colonies, there were adults that hadn't yet laid that were more alert, with increased occurrences of preening, walking, wing stretches and head turns however these adults were not included in analyses.

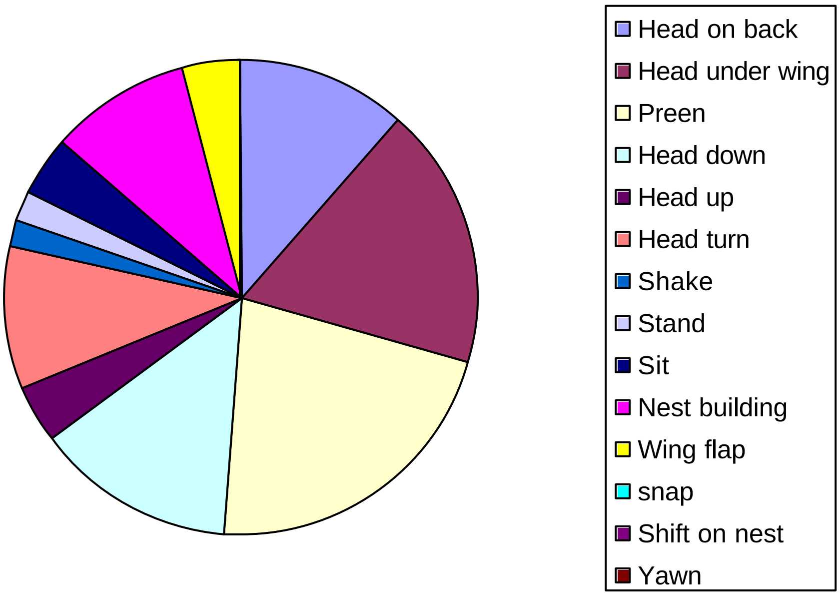

Figure 5.1.2*- Percentage frequency of total behavioural bouts during 30 minutes of neutral behaviour collected from Pelicans on eggs for approximately 1 month.*

5.1.2.2 Stimulation profile

During an approach, general alertness/vigilance increased markedly with an intruder, between 40-50m from the edge of the colony for Pelicans during late incubation (~1 month), and between 50-60m for Pelicans during early incubation (< 1 week).

This increase in vigilance can be seen as the sudden increases in total behavioural bouts in Figures 5.1.4 and 5.1.5., and resulted primarily as a significant increase in the frequency of the ‘head up’ position and in the frequency of ‘head turns’ (X= 94.55, p< 0.001) (see Figure 5.1.3). This behaviour continued increasing in frequency and intensity up until the approach was terminated. This happened once the target bird stood, walked away or displayed aggressive behaviour which occurred once the *approacher* was within 2m of the target bird.

There was also a significant decrease (X= 28.04, p< 0.001) in the frequency of the 'head on back' and 'head under wing' postures, which are thus interpreted to be signals of relaxed behaviour.

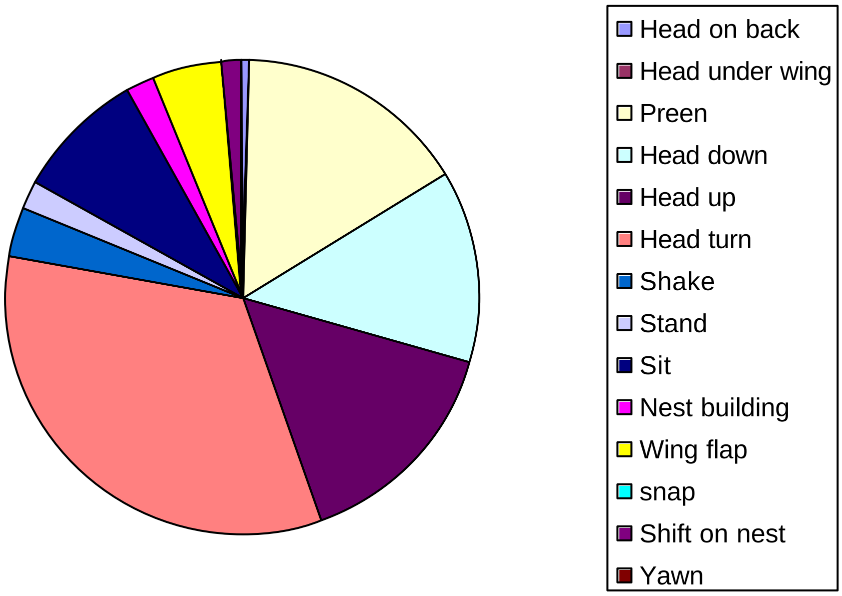

Figure 5.1.3- *Percentage frequency of behavioural bouts during 30 minutes of stimulation of Pelicans on eggs for approximately 1 month.*

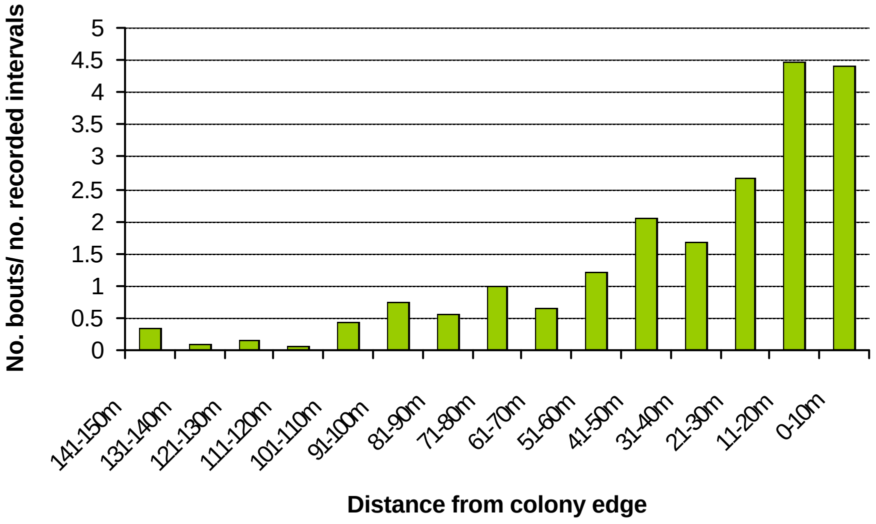

Figure 5.1.4- *Stimulation graph of total behavioural bouts during all approaches to pelicans on eggs for less than 1 week.*

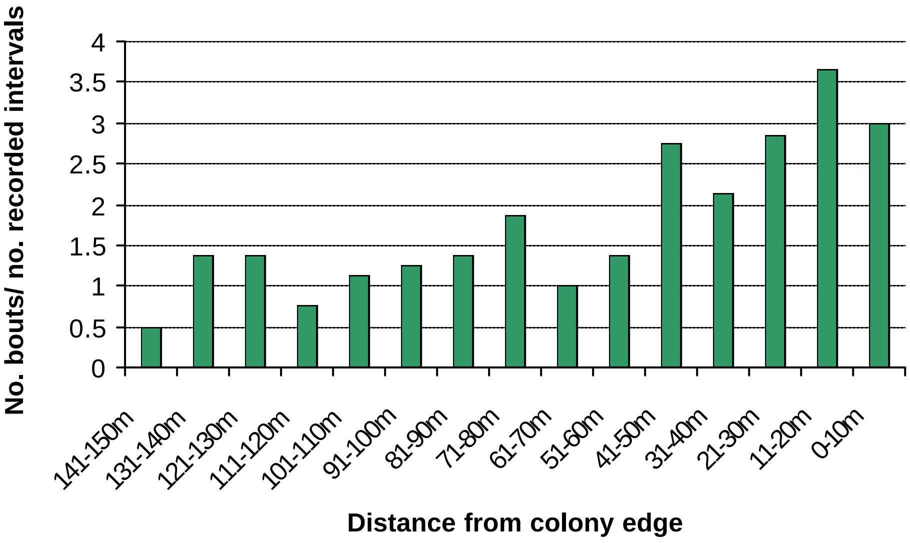

Figure 5.1.5- *Stimulation graph of total behavioural bouts during all approaches to Pelicans on eggs for approximately 1 month.*

5.1.2.3 Relaxation profile

Immediately after the *approacher* began to retreat from both colonies (early and late), there was a significant (X= 12.5, $p < 0.005$) increase in the frequency of preening, shifting and nest-building behaviour over that which occurred in the neutral colony. These signals are indicative of displacement behaviour, (Manning 1972) as they occur in larger amounts than in neutral behaviour and seem irrelevant to the situation in which they occur. Relaxation time was deemed to have finished once the behaviour indicating displacement again reached neutral levels. In most cases this was apparent when the target bird went back to its 'head on back' position and stayed this way for 4-5 minutes.

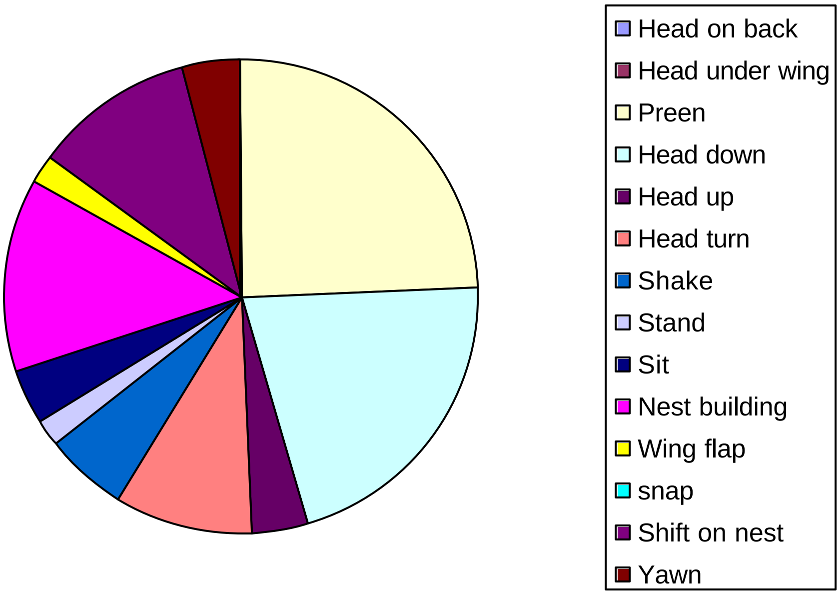

Figure 5.1.6- *Frequency of behavioural bouts during 30 minutes of relaxation time for pelicans on eggs for approximately 1 month.*

Based upon the differences in the frequency of behaviours during neutral and disturbed profiles, signals were classified into the following behavioural classes: relaxed, displacement, alert and aggressive (Table 5.1.1).

Table 5.1.1- *Classification of Pelican behaviour*

Behavioural Class	**Relaxed**	**Displacement**	**Alert**	**Aggressive**
Individual Behavioural	Head on back Head under wing Head down	Preening Nest-building Shifting on nest	Head up Head turns	Threat point Threat gape Growl

5.1.3 Pre-flight initiation distances

The distance at which the target individual (or those immediately adjacent) showed signs of taking flight or aggression, was termed the Pre-flight Initiation Distance (PFD) and was used to test for differences in how closely a human could approach depending upon species and the stage of the breeding season. This technique was also used to detect the development of short-term habituation.

Figure 5.1.7 describes the PFD for each approach carried out on Pelicans that had been incubating for less than 1 week and those that had been on eggs for approximately 1 month. It clearly shows a marked difference between the PFD's at the two different stages of the breeding season, where Pelicans at a later stage of incubation have lower PFD's and thus allow a closer approach than those at an earlier stage.

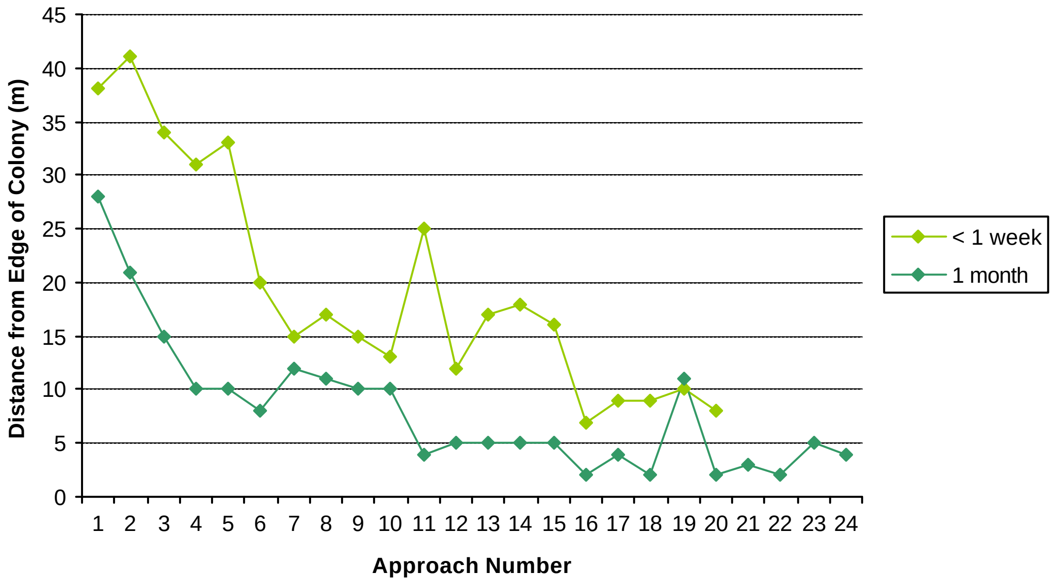

Figure 5.1.7- *Comparison of pre-flight initiation distances between Australian Pelicans on eggs for less than 1 week and approximately 1 month over 24 approaches on Penguin Island.*

A Chi-Squared (Goodness of Fit) test on the PFD's for Pelicans at both early and late stages of incubation indicated a very significant difference (X= 116.16, p< 0.001) between stages.

Furthermore, Pelicans at both stages of incubation appeared to show clear evidence of strong habituation to investigator disturbance in the gradual shortening of their PFD's over time. Figures 5.1.7 and 5.1.8 illustrate the differences in behaviour within the same colony over two days of approaches.

Figure 5.1.8*- Photos showing the differences in response between Pelicans early on within the approach-retreat experiment, and the same group a day later.*

To test the hypothesis that birds become habituated, a Student's T-test was used to determine whether there was a significant difference between the mean PFD's between days one and two of experimentation (as two days of approaches were common to both stages of the breeding season tested, see Section 5.1.1). The results were significant ($t = 3.534$ for early and $t = 3.447$ for late stages of incubation, $p < 0.01$), indicating that an increase in tolerance was in fact occurring between the two days and at both stages of the breeding season.

The number of approaches per day was limited to 10 to reduce negative impacts and allow sufficient time for normal feeding and incubating behaviour. The sharp peaks in Figure 5.1.7 indicate overnight gaps in the approach sequence, where the peak is at the first approach of the following day. This peak is higher than the last PFD of the previous day however it is still shorter than those of the initial approaches, indicating that the increase in tolerance experienced at both stages of incubation has lasted overnight and thus there may be the potential for long-term habituation.

5.1.4 Displacement behvaiour and relaxation times

The time taken to return to neutral behaviour (relaxation time) was not found to differ significantly between the two stages of incubation (t=0.0175), although relaxation times for Pelicans (~ 1 month) were found to be on average slightly longer than those for Pelicans (< 1 week).

A Student's T-test indicated that there was no significant difference between relaxation times over a two-day period for Pelicans in the early stages of incubation. However, a significant decrease (t=2.56, p< 0.05) in the average relaxation time of the second day for Pelicans at a later stage of incubation was evident (Figure 5.1.9), further indicating an increase in tolerance over two days. Relaxation times do not appear to have been effected by overnight breaks in the approach sequence.

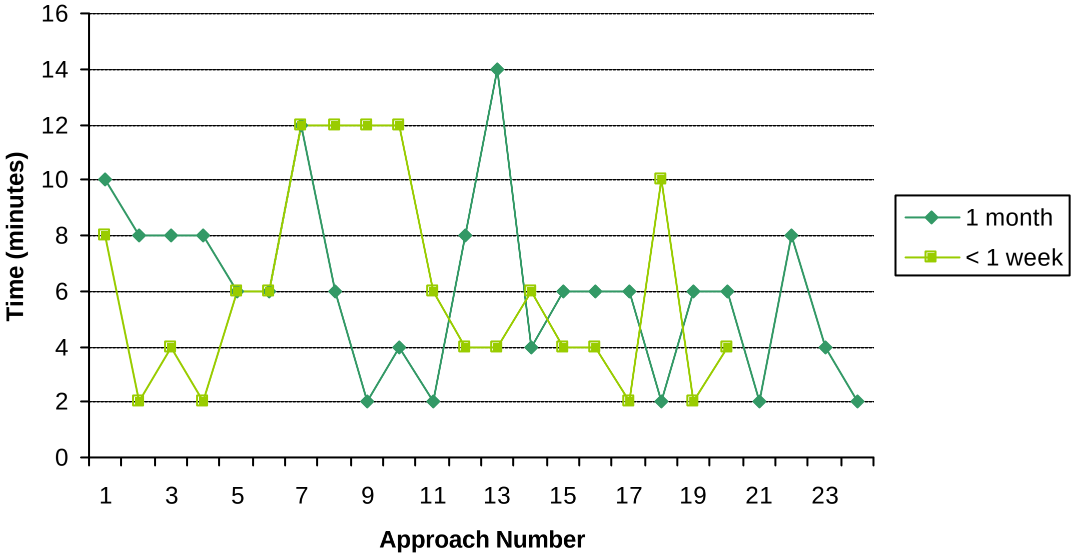

Figure 5.1.9- *Comparison of relaxation times between pelicans on eggs for less than 1 week and approximately 1 month (Day 1: 1-8, Day 2: 9-16).*

As can be seen from Figure 5.1.10 below, the types of behaviours during relaxation time are similar for Pelicans at both early and late stages of incubation, with the exception of early breeders spending more time in a relaxed position ('head on back', 'head under wing').

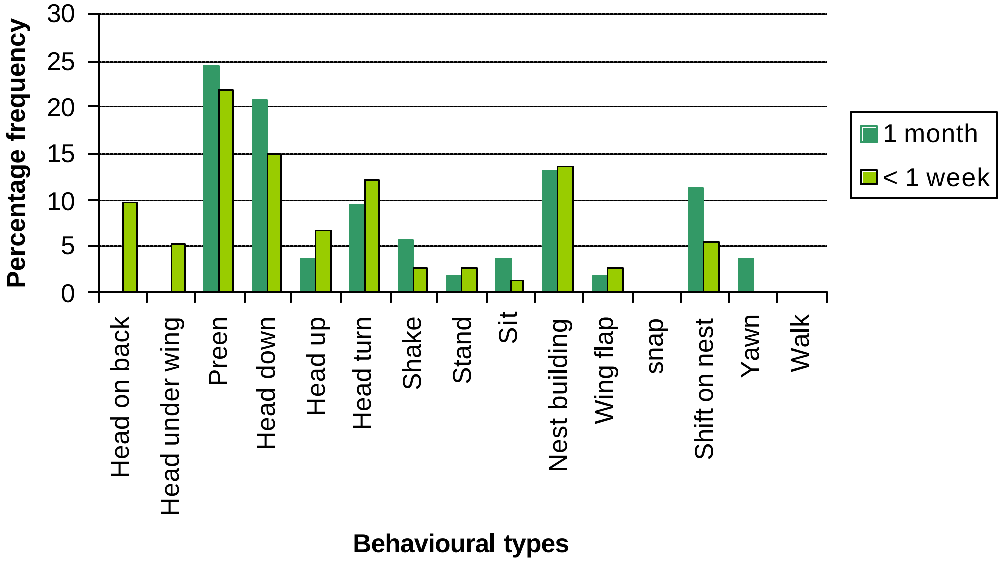

Figure 5.1.10- *A comparison of behaviour during relaxation times for early and late pelicans*

Displacement behaviour (preening, nest maintenance and shifting) increased in frequency directly after the *approacher* retreated from the colony edge, and gradually lessened over time (Figure 5.1.11).

A Chi squared (Goodness of Fit) test revealed that there was a significant difference (X= 44.927, p< 0.001), between displacement behaviour during relaxation times at early and late stages of incubation, where early Pelicans had significantly lower numbers of bouts (preening, shifting, nest building etc) than late (Figure 5.1.11).

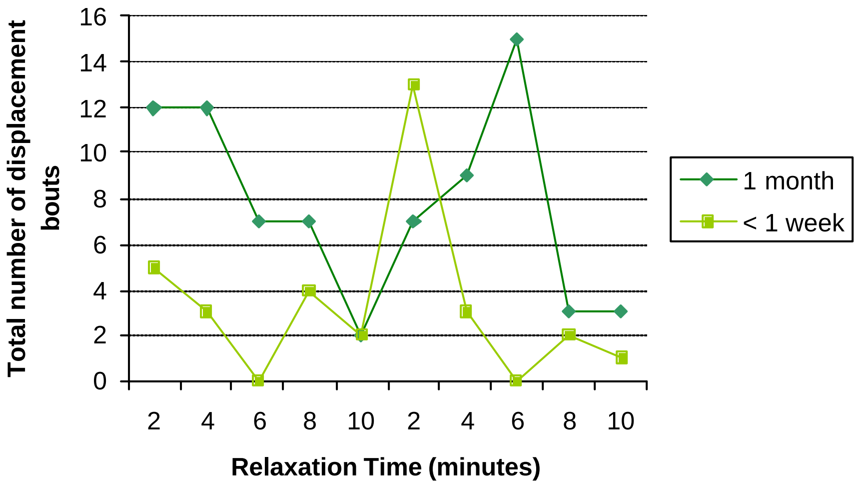

Figure 5.1.11*- Comparison of displacement behaviour during relaxation times over two stages of the breeding season and two days of experimentation (2-10 = 1 day)*

The average number of bouts of displacement behaviour was also found to lessen significantly between days one and two of approaches for both early (t=14.55, p< 0.01) and late Pelicans (t=13.585, p< 0.01), lending further evidence to the theory of habituation within this species.

5.2 Greater Crested Terns (Sterna bergii)

5.2.1 Introduction

A total of twenty-two approaches were carried out on a colony of Greater Crested Terns (*Sterna bergii)* over two phases of incubation in November 2003 at Lake Herschell, Rottnest Island. Nine approaches were conducted on Crested Terns that had been incubating for less than 48 hours (early) and thirteen on those that had been incubating for approximately 3-4 weeks (late). A lower number of approaches for the early breeders were necessary due to the sensitivity of the early breeding colony to disturbance and the strong likelihood of site desertion with continual approach.

Section 5.2 describes how Crested Terns responded to approach and why particular signals were chosen to denote neutral, alert and displacement behaviour. It then goes on to compare flight initiation distances (FID's) and PFD's, return times, relaxation times and displacement behaviours between early and late incubation phases, as well as presenting results that show evidence for short-term habituation. Lastly, it was noted that a relationship appeared to exist between PFD's and relaxation times in late Crested Terns (3-4 weeks) and this is further examined at the end of the chapter.

Individual bouts of single behaviours could not be detected to the same extent as with the Australian Pelican and the Brown Noddy, due largely to the faster speed with which the Crested Terns responded to approach and a highly detailed behavioural repertoire. Therefore Section 5.2 does not contain detailed behavioural profiles and statistically significant signals for neutral, alert and displacement behaviours. Instead, a comprehensive series of behavioural events is described in the order in which they occurred and reference is made to relevant literature to support the classification of behaviours (Table 5.2.1).

5.2.2 Crested Tern behaviour in response to human approach

At a very early stage of incubation, the Crested Terns on Lake Herschell showed no behavioural signals that indicated their intention to move from their nests until up-flight was initiated. Five out of nine approaches to Crested Terns during early (< 48 hours) incubation resulted in the rapid mass up-flight of the colony, (including both nesters and prospectors/pre-breeders).

The approaches to early nesters were carried out during the early morning and again in the late afternoon. There were more pre-breeders within the colony during the early morning (approaches 1-4), whereas they were absent during the afternoon approaches (5-9). These pre-breeders were observed to have an effect upon the FID of the nesting terns as they responded to disturbance at greater distances causing premature up-flight in nesting birds. For these reasons, the number of approaches was kept to a minimum (9), thus reducing the possibility of early site desertion and minimising the effects of the adult leaving the egg unattended.

Crested Terns that had been incubating for between 3-4 weeks however, showed a sequence of behaviours that gave an indication of their intentions to move away from the nest. The sequence started with a general increase in alertness (‘head up’) from approximately 40-50 meters away, followed by alarm calls at 25-30 meters from the edge of the colony, an increase in the frequency of ‘head turns’ and finally standing on the nest and occasional ‘wing-lifts’, with the bird often walking a small distance away from the nest rather than taking to the air. Approaches were stopped once standing or wing-lifts was observed.

Behavioural signals were classified in Table 5.2.1 depending upon when during the approach-retreat sequence an increase in each behaviour was observed. Additionally, Manning (1972), Dunlop (1986) and Dunlop (1987) were used to determine typical behavioural signals common in this species.

Table 5.2.1- *Classification of Crested Tern behaviour*

Behavioural Class	**Relaxed**	**Displacement**	**Alert**
Individual Behaviour	Sitting, head on back	Preening Nest-building Shifting on nest Snapping at neighbours	Head up Head turns Alarm calls Wing lifts

5.2.3 Pre-flight initiation distances and flight initiation distances

Measurements of PFD’s were used to determine whether a difference existed between different stages of the breeding season, in terms of the distance to which nesting Crested Terns could be approached, as well as providing an indicator by which to test for habituation.

A marked difference was observed in the reactions of the Crested Terns to human approach between early (<48 hours) and late (3 weeks) stages (see Figure 5.2.1). Approaches made to birds on eggs for less than 48 hours resulted in much larger

PFD's and FID's than the same colony (although different individuals) approached after 3-4 weeks of incubation. A Students t-test revealed that there was a very significant ($t= 4.2$, $p< 0.001$) difference in PFD's between early and late stages of the breeding season. Figure 5.2.1 shows PFD's for early Crested Terns are in general larger and more variable than those for late Crested Terns. Therefore birds that had been incubating for a longer period of time, allowed a closer approach.

There was also a difference between results for early terns, depending upon whether approaches were made in the early morning or afternoon (see Figure 5.2.1). Pre-breeders were present in the early morning and initiated rapid up-flight in nesting birds, while the afternoon approaches all resulted in PFD's at more regular and shorter distances. The FID of 124m in early terns during the second approach is thought to be due to silver gull activity and was not a direct result of human approach.
A significant ($t=3.176$, $p< 0.01$) inverse relationship exists between successive approaches and PFD's for Crested Terns during a late stage of incubation (> 3 weeks) (see Figure 5.2.1). This could represent an increase in tolerance and thus short-term habituation in late terns.

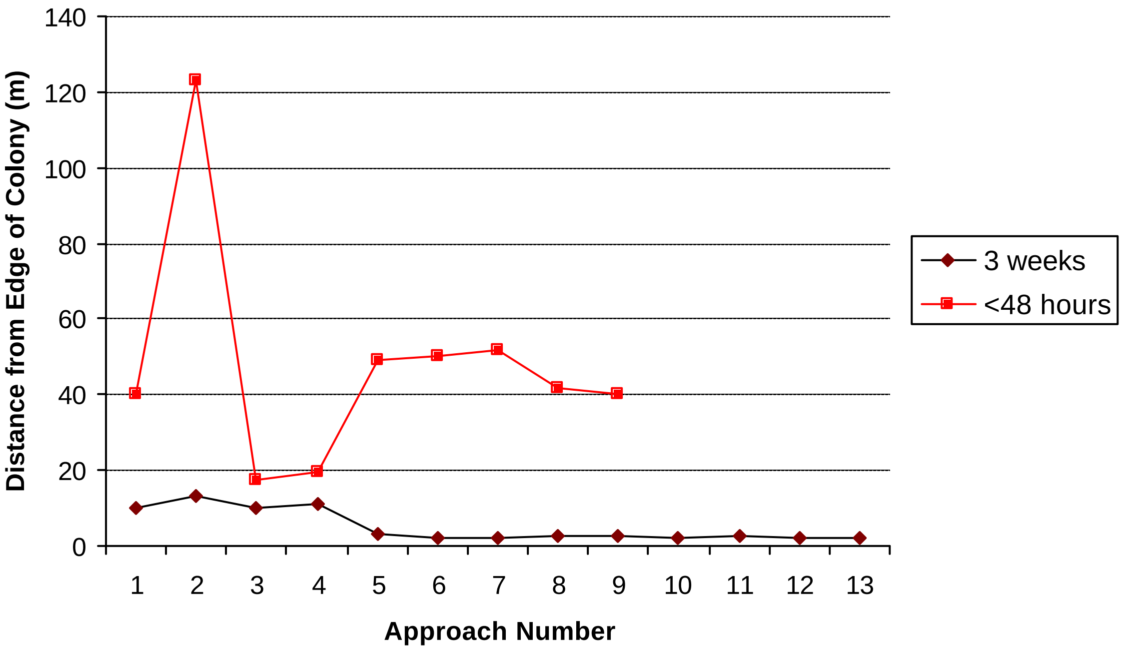

Figure 5.2.1- *Comparison of pre-flight and flight initiation distances between early and late nesting Crested Terns at Herschell Lake, Rottnest Island.*

5.2.4 Return times

The time taken to return to incubation was recorded for target birds and is displayed for both stages of the breeding season (Figure 5.2.2). It seems likely that short-term habituation is occurring at an early stage of the breeding season from the dramatic drop in return times within the first three approaches and then the steady flattening out of the curve. Late terns did not show any evidence of habituation through their return times.

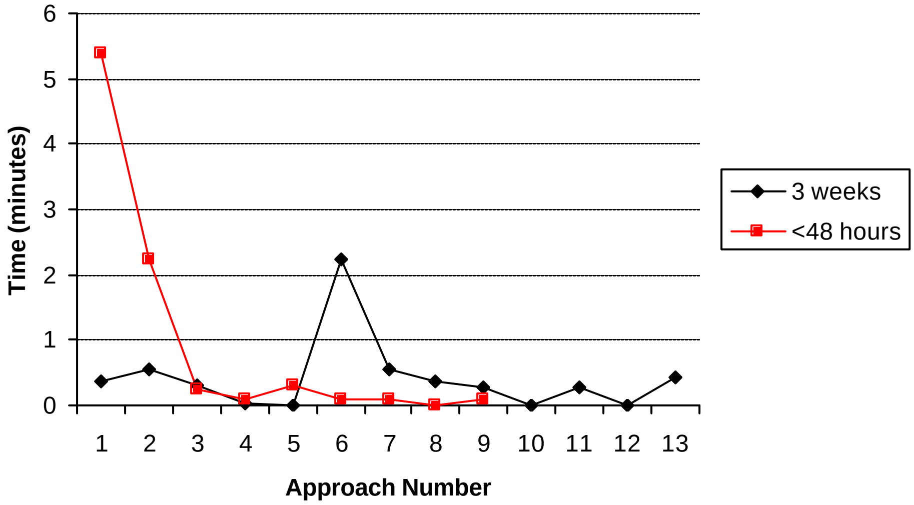

***Figure 5.2.2-** A comparison of individual return times of early and late breeding Crested Terns on Herschell Lake, Rottnest Island.*

There is no significant difference (t= 0.853) between average return times at the two stages of the breeding season.

5.2.5 Displacement behaviour and relaxation times

The types of behaviour that were monitored after the approach included preening, shifting on the nest and nest maintenance. In the case of early terns, the first two approaches caused them to avoid the nest site for several minutes (see Figure 5.2.2). After following approaches incubation resumed almost immediately after the disturbance and there was very little displacement behaviour observed. There was more displacement behaviour observed in the late terns, with “border disputes” frequently occurring. Relaxation time was most often filled with preening and nest maintenance behaviour at both stages of incubation.

The average relaxation times decreased significantly over the approach sequence at a late stage of incubation (t=2.529, p< 0.05), indicating an increase in tolerance and therefore possible short-term habituation. A statistical assessment of the relaxation times of early terns was not performed due to variability in the data gathered, however it also appears that habituation may be occurring.

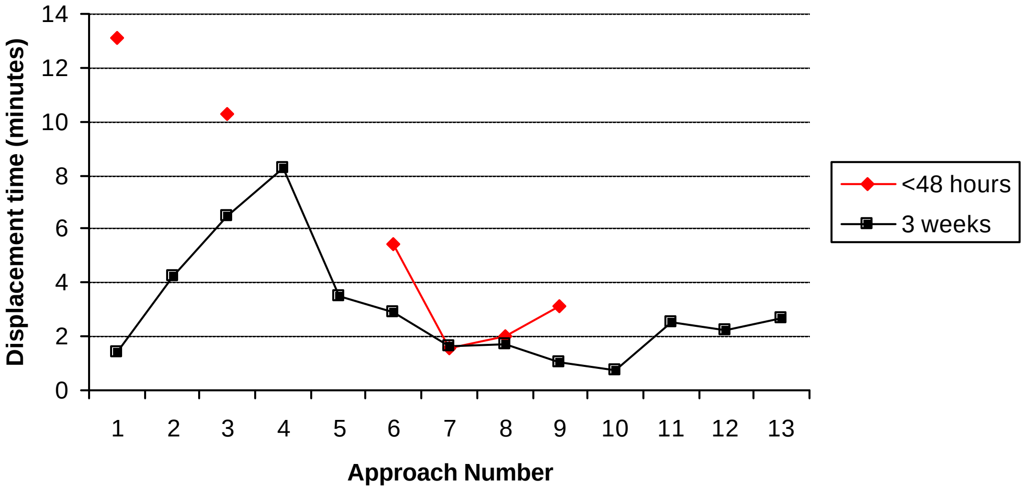

Figure 5.2.3- *Comparison of total relaxation times between early and late Crested Terns, Herschell Lake, Rottnest Island.*

5.2.6 Comparison between PFD's and relaxation times

Figure 5.2.4 describes the relationship between PFD's and relaxation times at a latter stage of incubation. It is noticeable that the two graphs follow each other very closely and this relationship was subsequently tested for linear correlation using a product-moment correlation (Ebdon 1977, Figure 5.2.5).

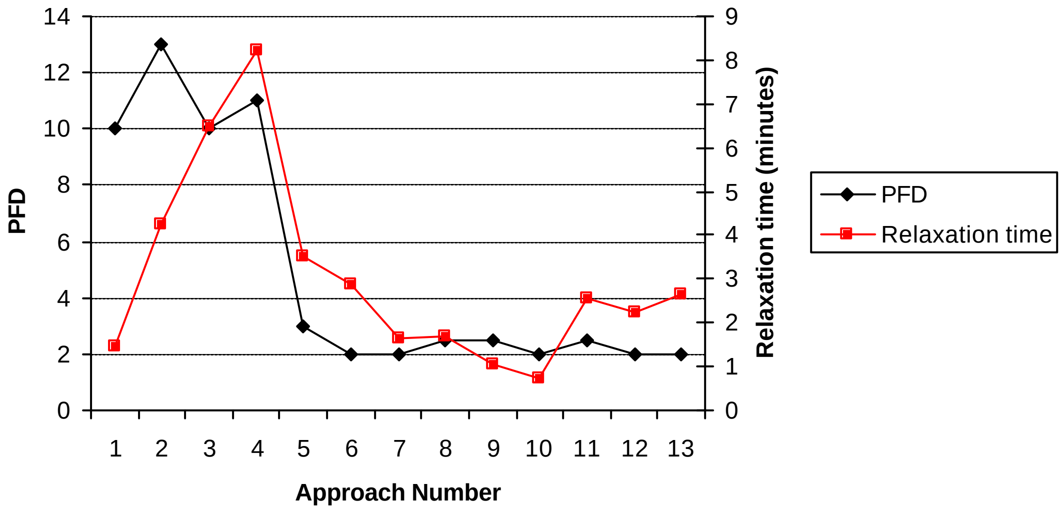

Figure 5.2.4*- Pre-flight distances and the time taken to return to normal behaviour (relaxation time) for Crested Terns on eggs for approximately 3 weeks.*

A strong positive linear correlation (R= 0.820, p< 0.01) between PFD's and the time taken to return to normal behaviour was found in Crested Terns on late eggs (Figure 5.2.5), however no such relationship was noted in early terns.

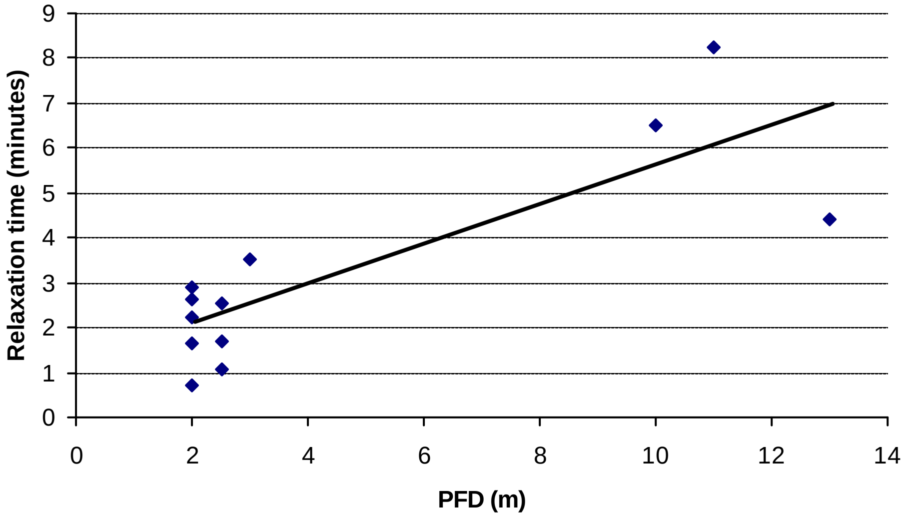

***Figure* 5.2.5**- *Linear regression between pre-flight distances and relaxation times in late Crested Terns*

This relationship suggests that relaxation time decreases as PFD's decrease, or the closer that an approach is tolerated, the shorter the time taken to return to normal behaviour.

5.3 Brown Noddies (Anous stolidus)

5.3.1 Introduction

Nesting Brown Noddies (*Anous stolidus*) were approached a total of 25 times on Lancelin Island on three separate occasions, the 6th, 7th and 20th of December 2003. Both stages of the breeding season (pre-breeders with nests and breeders on eggs) were tested at the same time as this species forms a colony comprising adults in all stages, from courting to nest building and incubating eggs of varying age. Approaches were limited to ten per day to reduce the time spent within the colony.

Section 5.3 firstly outlines the signal behaviours of disturbance and how these were identified. It then goes on to examine the differences in FID's, return times, relaxation times and displacement behaviour between pre-breeders and breeders (incubating birds).

5.3.2 Brown Noddy behaviour in response to human approach

There was a high level of 'background' activity evident within even the neutral/ undisturbed colony. (Behaviour included up-flight, preening, snapping at passing birds, aggression calls and shifting on nests). This was most likely caused through the activity of pre-breeders courting and searching for nest sites. These factors made it difficult to differentiate between normal and disturbed behaviours, and in fact there was no significant difference behaviour neutral and stimulation profiles.

However Brown Noddy behaviour changed in relative frequencies between neutral and relaxation profiles. The behaviour of pre-breeders and breeders were different enough to warrant displaying data for both stages of the breeding season.

5.3.2.1 Neutral profile

Neutral behaviour for pre-breeders typically consisted of the adult standing on the nest with a high frequency of up-flight and preening, which was larger than that displayed in breeders. A high level of activity surrounded these birds as they engaged in territorial disputes and stole nest material form neighbouring nests (Figure 5.3.1).

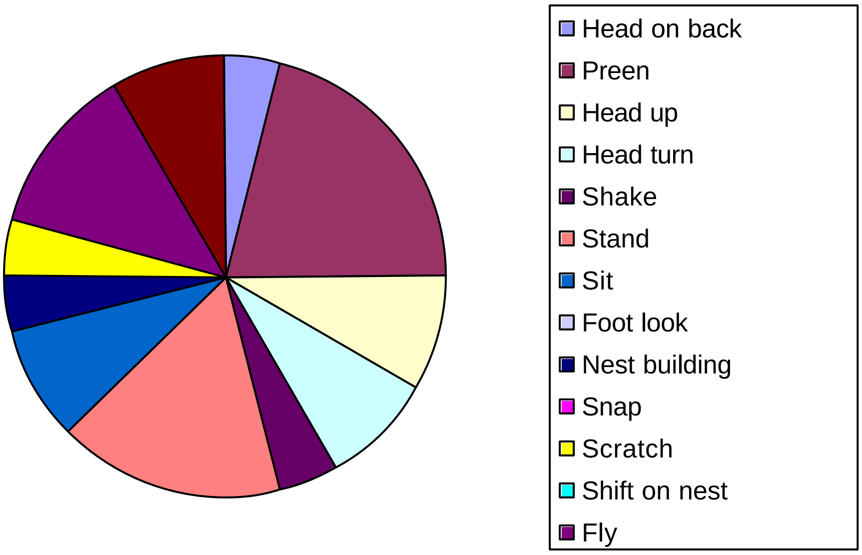

Figure 5.3.1- *Percentage frequency of total behavioural bouts during 8 minutes of neutral behaviour collected from pre-breeders in the Brown Noddy colony on Lancelin Island.*

Breeding Brown Noddies predominantly sat in an incubating position with their head on their back. Many took notice of the activity of the pre-breeders, which is demonstrated by ‘head turns’ and ‘rapid head movements’ (Figure 5.3.2).

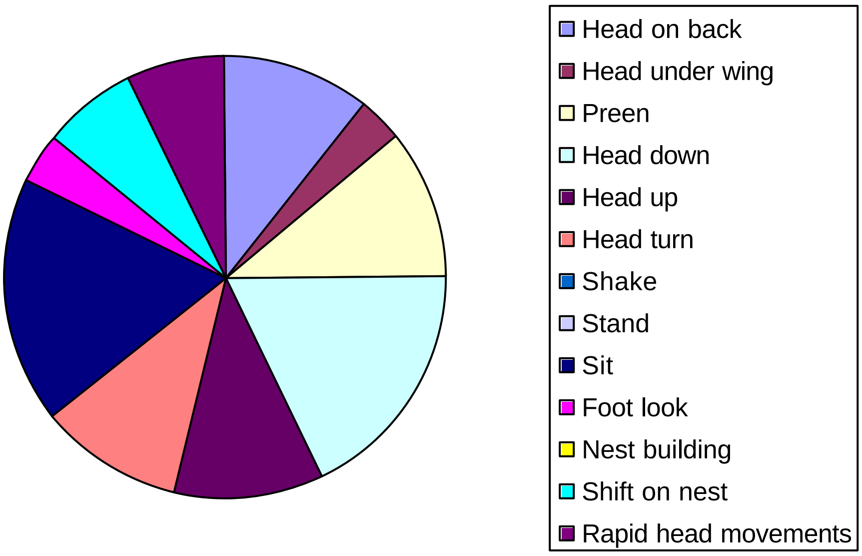

Figure 5.3.2- *Percentage frequency of total behavioural bouts during 5 minutes of neutral behaviour collected from breeders in the Brown Noddy colony on Lancelin Island.*

5.3.2.2 Stimulation profile

Behaviour during the approach did not differ significantly from neutral levels until the *approacher* came within 2 meters of the target bird. The response of pre-breeders was to fly away at approximately 2 meters and most breeders remained on the nest where they displayed ‘head turns’ and ‘rapid head movements’.

5.3.2.3 Relaxation profile

During relaxation time, both breeders and pre-breeders experienced a marked increase in 'foot looks' and shifting on the nest. In fact, pre-breeders did not display foot looks, snapping or shifting during neutral behaviour but displayed counts of 15, 5 and 6 (respectively) during 16 minutes of relaxation time (Figure 5.3.3). This increase is interpreted as significant although the zero values prevent a Chi squared test to compare frequencies statistically.

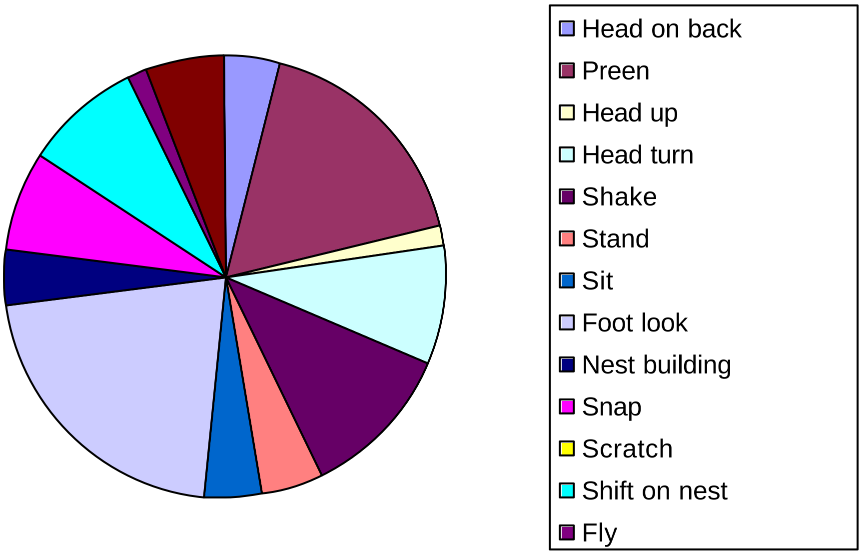

Figure 5.3.3- *Percentage frequency of total behavioural bouts during 16 minutes of relaxation time collected from pre-breeders in the Brown Noddy colony on Lancelin Island.*

Breeders displayed a significant increase in foot looks, head turns, shifting on the nest and rapid head movements from neutral levels (X = 167.12, p< 0.001). Interestingly, preening decreased from neutral to relaxation behaviour in both breeders and pre-breeders, and was not included as a displacement signal (Figure 5.3.4).

There was a difference in the behavioural signals indicating displacement between pre-breeders and breeders. Breeders predominantly displayed significantly (X = 7.065, $p < 0.05$) more shifting, foot looks and rapid head movements that pre-breeders during relaxation time, whereas pre-breeders displayed more preening and shaking than breeders after an approach (Figure 5.3.4).

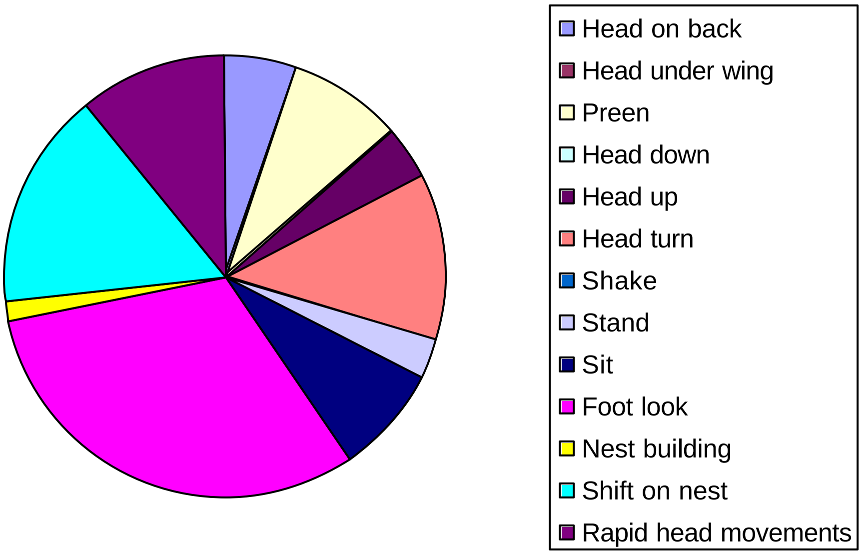

Figure 5.3.4- *Percentage frequency of total behavioural bouts during 19 minutes of relaxation time collected from breeders in the Brown Noddy colony on Lancelin Island.*

As a result of these analyses, variations in Brown Noddy behaviour were classified into relaxed, displacement and alert behavioural signals.

Table 5.3.1- *Classification of Brown Noddy behaviour*

Behavioural Class	**Relaxed**	**Displacement**	**Alert**
Individual Behaviour	Head on back Head under wing	Nest-building Shifting on nest Foot-looks	Head up Head turns Rapid head movements

5.3.3 Pre-flight initiation distances and flight initiation distances

Flight Initiation Distances (FID's) and PFD's did not vary to any significant degree between pre-breeders (on nest only) and breeders (on an egg) and in all 25 cases the *approacher* was able to reach a distance within 2 meters of the target bird before flight initiation responses were observed.

However up-flight was initiated in 100% of approaches to pre-breeders, while 11 out of 14 approaches made to breeders did not result in the birds leaving the nest site even after the *approacher* extended a hand towards them.

5.3.4 Return times

The time taken to return to the nest site after a disturbance was recorded for both breeders and pre-breeders. On average, pre-breeders took longer to return to their nest site than birds with eggs (Figure 5.3.5). A statistical analysis comparing the two means from both stages of the breeding season from the 6th and 7th of December, resulted in a significant difference (t=2.824, p=0.01) being evident between pre-breeders and birds on eggs. (This test excluded the outlier on the 7th as the pre-breeder observed may not have been sitting on a nest, but a branch). The results from the 20th were not included in this analysis as they suggest that these birds may have been at a different stage of incubation than at earlier dates due to their shorter return times and longer relaxation times (a possible result of increased site attachment).

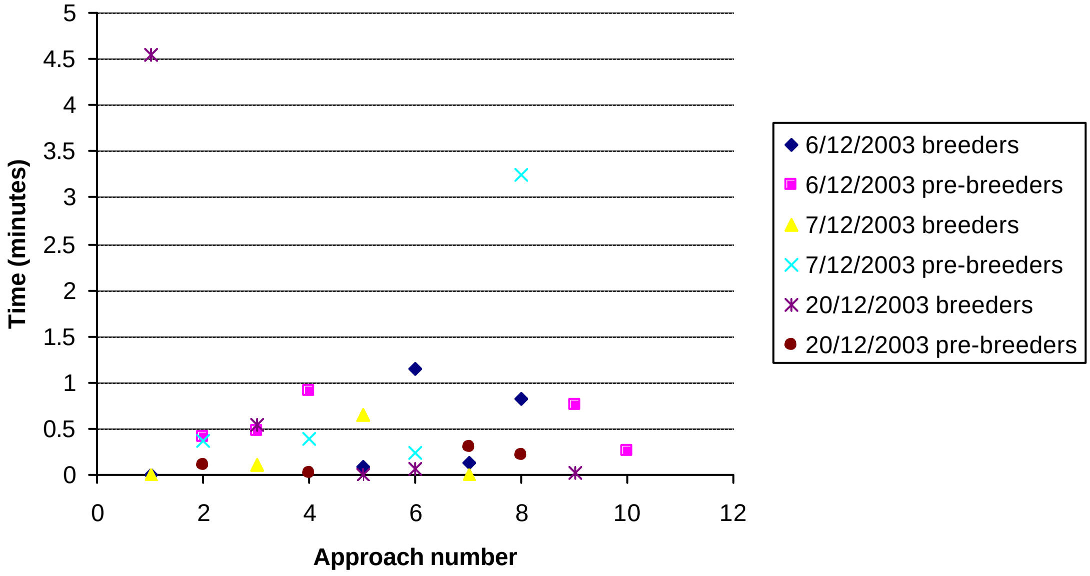

Figure 5.3.5- *Comparison of return times between Brown Noddies on nests and on eggs on the 6th, 7th and 20th of December 2003 on Lancelin Island.*

5.3.5 Displacement behaviour and relaxation times

Figure 5.3.6 shows the relative frequencies of particular behaviours as a percentage of the total displacement bouts recorded from the 20th of December 2003. Displacement signals for breeding Noddies are more commonly foot looks and shifting whereas pre-breeders more commonly engage in preening and nest-building to a lesser extent.

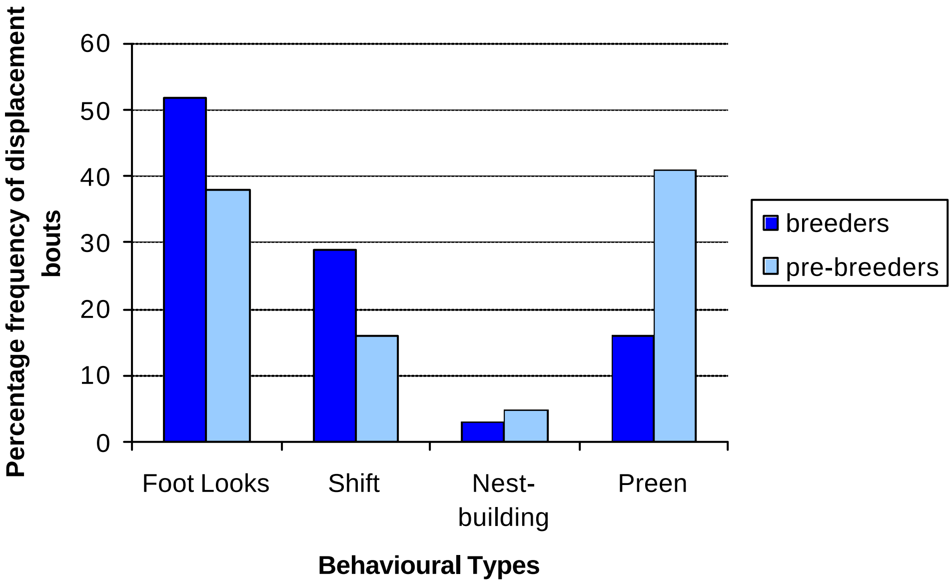

Figure 5.3.6- *Comparison of displacement behaviour between Noddies on eggs and on nests- 20/12/03*

Figure 5.3.7 shows a range in the differences between data collected at two stages of the breeding cycle, at dates two weeks apart. It can be seen from Figure 5.3.7 that in general, pre-breeders take longer to relax after a disturbance than those birds on eggs. In fact, statistical analysis revealed a significant difference (t= 3.07, p= 0.01) between the relaxation times of breeding and pre-breeding birds.

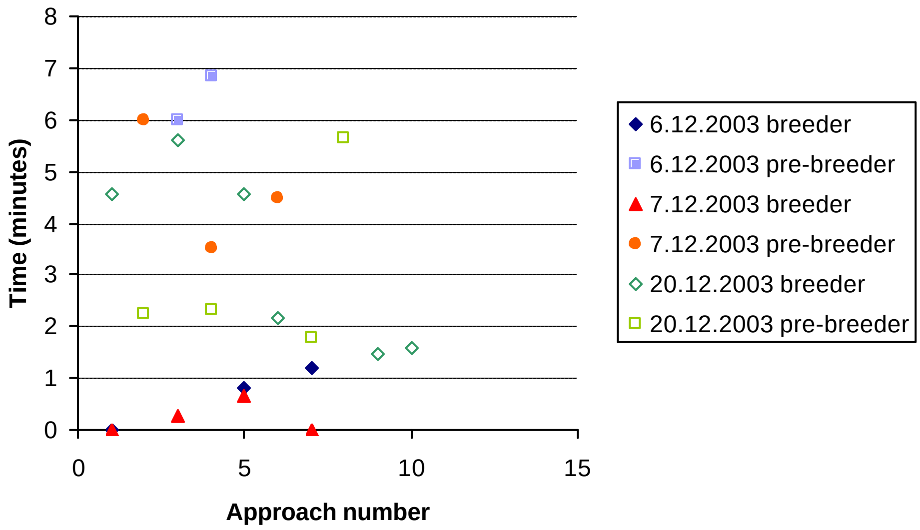

Figure 5.3.7- *Comparison of relaxation times between Noddies on nests and on eggs over the three experimentation dates*

The relaxation times for pre-breeders were only measured to an upper limit of 6 minutes. This was due to the difficulty in distinguishing disturbed behaviour with that normally attributed to this stage of the breeding cycle. It involved a much higher level of activity than that of birds on eggs and was exacerbated by the activity and rivalry of birds still courting and scouting for nest sites (ie: preening and nest maintenance behaviour could have been ‘natural’).

The difference between the relaxation times for birds on eggs on the 6th and 7th of December and the 20th of December is however worth noting. The results are from different parts of the colony and therefore do not represent the same birds at a later stage of incubation. However, birds on the 20th took on average significantly (t= 3.84, p=0.01) longer to relax than those from an earlier visit.

It can also be seen from Figure 5.3.7 that the breeders graph from the 20/12/03, and potentially that from the 6/12/03, appears to indicate habituation. On analysis, the data from 20/12/03 showed a significant (t= 7.64, p= 0.01) decline in relaxation times.

Figure 5.3.7 suggests that pre-breeders are displaced for longer periods of time than are birds on nests. This graph along with Figure 5.3.6 demonstrates that displacement behaviour is more intensive for incubating birds (ie: more bouts during a shorter time frame).

6. GENERAL DISCUSSION AND GUIDELINES FOR VISITOR MANAGEMENT

6.1 Critique of the Methodology

There are several limitations acknowledged within the methodology used for this research. Firstly, greater statistical validity may have been achieved if more data points were gathered for all species, particularly for Crested Terns. However, there were several issues associated with the continual disturbance of all species that had to be balanced carefully with gathering sufficient data points. In the case of Crested Terns the primary risk was of site desertion and the potential for this species to abandon breeding attempts if no other site was located. In the case of Brown Noddies, the time spent within the colony was limited to reduce the impacts on those birds still courting or mating. Therefore a trade-off between gathering enough data points for statistical validity and limiting the disturbance to the breeding colonies had to be made.

Better results would have been achieved if behavioural data in individual bouts in the case of Crested Terns had been gathered. This information was necessary to statistically validate observational differences in behaviour between a neutral and disturbed colony. However a lack of initial understanding of the complex behaviour of this species resulted in observations of behaviour being documented and interpreted using references to other work. Therefore a detailed investigation into the behavioural repertoire of a seabird species should preclude any future experimental research of this nature, where small changes to the broader methodology may need to be made to accommodate species with detailed behavioural repertoires.

6.2 Differences in Behaviour

6.2.1 Differences between species

Results presented in the previous chapter indicate that all three species investigated varied in their responses to human approach. This was reflected in their PFD's or FID's, the time taken to return to the nest site or to normal behavioural levels, in their displacement behaviour and their ability to habituate to repeated approaches over a short period of time.

Table 6.1- *Comparisons of species behaviour and estimated CAD's*

Species	Stage of the breeding season	Largest PFD or FID (m)	Longest relaxation time (mins)	Longest return time (mins)	Habituation occurring	Habituation rate (mean decrease in PFD's)	CAD (m)
Australian Pelican	Early	42	12	Na	yes	1.5	42
	Late	28	14	Na	yes	0.875	28
Crested Tern	Early	52	13	5.5	yes	1.11	52
	Late	13	8	2.3	yes	0.2	13
Brown Noddy	Early	2	7	3.25	unknown	unknown	5
	Late	2	5.7	4.5	unknown	unknown	5

There are several factors that can affect CAD's in breeding seabirds, examples being colony size, food stress, the stage of the breeding season and the frequency or intensity of disturbance (Anderson and Keith 1980, Cooke 1980, Dunlop 1996, Nisbet 2000, Dunlop 2002, Blumstein *et al* 2003). The three islands, Penguin, Rottnest and

Lancelin vary considerably in visitor numbers. This could help to explain differences in response if the same species had been investigated over two different locations however it is more likely that species-specific traits were responsible for the variation in this case.

It is thought that species-specific anti-predator behaviour has a significant and important effect upon the differences in CAD's between species (Blumstein *et al* 2003). Moreover, Blumstein *et al* (2003) state that FID's are a species-specific trait and managers need not necessarily collect site-specific approach-response data if the species' FID is already known. However, while individual species may exhibit certain tolerance limits to human disturbance (as a result of their lifestyle, see Section 2.2.4) a history of human activity can increase this innate tolerance, resulting in the habituation of the species and thus reduced CAD's.

Figure 6.1 describes how PFD's and FID's differ over the three species tested. It is also noticeable that these measurements differ between the two stages of the breeding season tested for each species.

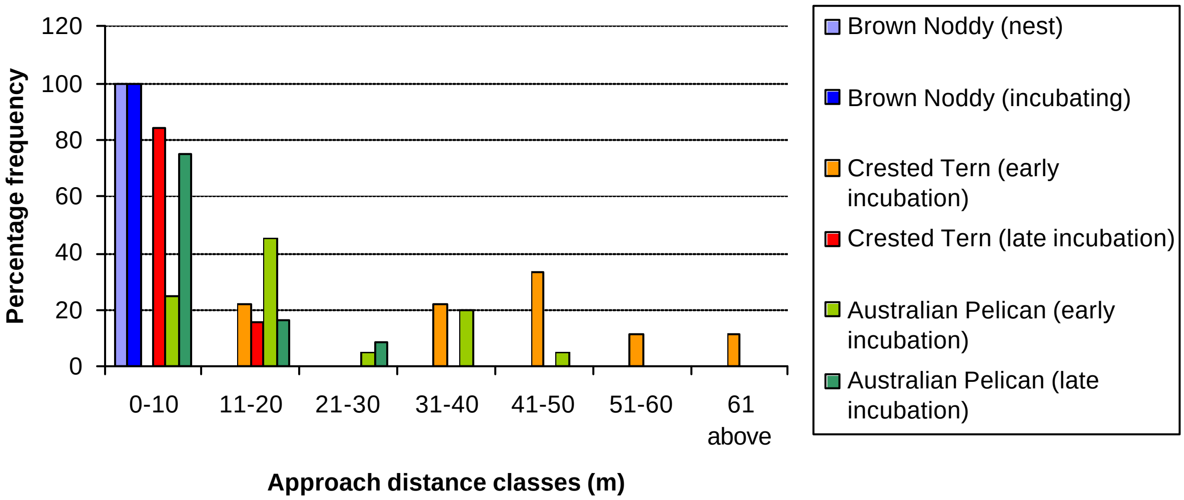

Figure 6.1- *The differences in the pre-flight distances or flight initiation distances between species and the range within each species at two stages of the breeding season.*

6.2.2 Differences between phases of the nesting season

6.2.2.1 Australian Pelicans

Pelican behaviour was found to vary significantly between early (< 1 week) and late (~1 month) stages of incubation. This was observed in the differences in PFD's and the intensity and frequency of displacement behaviour during the relaxation period (see Figures 5.1.3 and 5.1.6).

The stimulation graphs comparing stages of the breeding season (Figures 5.1.4 and 5.1.5) demonstrate the effects of increasing site attachment on the behaviour of breeding Australian Pelicans, in that Pelicans that had been incubating for longer, were more strongly attached to the nest site than were those that had recently laid. These data show that a greater number of behavioural bouts occurred during stimulation, (particularly as the *approacher* got closer to the colony) in Pelicans at a later stage of incubation than in those at an earlier stage.

This difference in behaviour between early and late stages of incubation may be explained by a conflict between two opposing tendencies in Pelicans at a late stage of incubation; whether to remain incubating or leave as a perceived predator approaches. The earlier breeders may have had less motivational conflict towards the tendency to leave the nest site, as they were less attached to the site than the birds that had been incubating for approximately 1 month. Pelicans (< 1 week) thus moved from the nest site while the *approacher* was further away, resulting in higher PFD’s than for more highly site attached birds.

This ‘indecision’ in the Pelicans at a late stage of incubation translated into behaviour such as head turns, preening and nest building activity. This type of behaviour is termed ‘displacement behaviour’ and refers to patterns that seem irrelevant to the situation in which they appear (Manning 1972) yet have increased in frequency from neutral levels. For example, preening is thought to appear when the instincts to incubate and escape are equally balanced. This is separated from natural preening to clean feathers or when no other behavioural tendencies are strong (Manning 1972). Increased displacement behaviour has in turn affected relaxation times exhibited by Pelicans at a later stage of incubation, causing them to be on average longer than those for Pelicans that had been incubating for less than 1 week.

Longer relaxation times and high levels of displacement behaviour may be detrimental to breeding productivity within this species as during this time, normal incubating, feeding or social behaviours are replaced by behaviours irrelevant to breeding (Manning 1972). Additionally, the time spent away from the nest site increases the risk of predation, egg heating or cooling and displacement behaviour is an indicator of physiological stress (Carney and Sydeman 1999, Giese 1995, Lord *et al* 2001). The extent to which this may affect the success of this colony would depend heavily upon the frequency and intensity of disturbances and the effect of stress on adult survivorship.

6.2.2.2 Greater Crested Terns

The behavioural responses and consequently the PFD's and FID's of Crested Terns differed significantly between early (< 48 hours) and late (3-4 weeks) stages of incubation at Herschell Lake on Rottnest Island. There are likely several reasons for these differences.

Firstly, Crested Terns lay in synchrony as a predator-defence strategy (Dunlop 1986). A consequence of this is that the size of the breeding colony changes with the stage of the breeding season, as initially a few birds lay and gradually more and more join the colony. As colony size has an effect on the responses of many breeding waterbirds to human disturbance in that it generally increases tolerance (Burger and Gochfeld 1991), colony size may have influenced this difference, where Crested Terns that had been incubating for 3-4 weeks allowed a much closer approach than did the birds that had only just laid (<48 hours).

Secondly, site attachment also increases with the time spent incubating (see Figure 2.3). The difference in site attachment between the two stages of incubation would have certainly had an effect upon behavioural responses. Crested Terns on eggs for 3-4 weeks would have experienced stronger site attachment, allowing a closer approach and facilitating short-term habituation to repeated approaches.

Thirdly, the presence of pre-breeders in the early colony was observed to have an impact on the behaviour of the nesting birds causing the whole colony to take flight on several occasions. Relaxation times were longer in birds at an early stage of incubation than in the later, probably due to the increased disruptive activity of the pre-breeders after a disturbance. Low site attachment of the early breeders and the presence of pre-breeders are likely reasons for flushing to have occurred at some approaches and larger PFD's being evident than for later birds.

Return times were not found to differ significantly between early and late stages of incubation. This result is unusual, in that greater site attachment at later stages of incubation would normally result in comparatively shorter return times. However due to the increased size of the colony between early and late stages, it may be that the return times of the late colony were delayed due to increased "traffic" in the airspace above the colony after a disturbance, as there was always a percentage of the colony that took to the air as a result of human approach, adding to the numbers that were leaving and entering the colony under natural conditions.

The increase in colony size between early and late incubation phases may also explain the higher intensity (greater amounts during a shorter period of time) of behaviour after a disturbance in the late colony. While late nesters had (on average) shorter relaxation times than early, the amount of behaviour observed during this time was greater than that for Crested Terns in the early colony. This was likely due to the increased interactions between birds nesting in a denser, more extensive colony at a later stage of incubation.

Therefore behaviour observed during relaxation time would have consisted of both displacement and site defence behaviours. This could have implications for the impacts of frequent human disturbance to a colony during a late incubation phase as continued disturbance would result in prolonged stress levels due to interaction between birds as well as from a direct response to human approach.

6.2.2.3 Brown Noddies

Unlike Crested Terns and Australian Pelicans, Brown Noddies nesting on Lancelin Island were highly tolerant of human approach probably largely due to their pelagic lifestyle (ie: this species evolved nesting on oceanic islands with few mammalian predators). Thus variations in response to human approach between two stages of the breeding season (birds still nest-building and those incubating eggs) were subtle, however some significant behavioural differences were observed.

For example, pre-breeders (took significantly longer than breeders to return to their nest site after disturbance. This is presumably attributable to stronger site attachment of birds on eggs opposed to birds with a nest only. In many cases, breeding Noddies refused to leave the incubating position even when lightly touched by the research assistant. This strong attachment to the nest could also be a function of this species' lack of anti-predator strategies with respect to land mammals, as when a predatory bird flies overhead, a completely different scenario is played out, with all birds taking to the air in an aggressive mob (pers obs).

Relaxation times were also found to significantly differ between stages of the breeding season. The greater relaxation times for pre-breeders reflect the larger amount of behaviour observed at this stage. This included a larger amount of preening than was observed in breeders (Figures 5.3.3 and 5.3.4). However unlike Australian Pelicans and Crested Terns, incubating Brown Noddies displayed fewer displacement bouts after a disturbance than pre-breeders. An explanation could be that the behaviour observed in pre-breeders after an approach was probably exacerbated by the need to defend nest sites and nesting material from other birds as much as being a direct result of disturbance.

However several researchers have found that intra-species interactions (in this case competition for space and nesting material) caused by human disturbance can have an effect upon the breeding success of a colony (Kury and Gochfeld 1975, Latta Hand 1980, Burger and Gochfeld 1994) and therefore this behaviour, if not formally termed 'displacement behaviour', could have negative effect upon the success of the Brown Noddy colony if it is frequency disturbed.

Although breeders exhibited lower levels of behaviour after a disturbance than did pre-breeders, this behaviour occurred during a relatively short period of time, in the form of foot-looks and shifting on the egg. These highly intense (many during a short period of time) forms of behaviour are likely to have been reflected internally in the form of physiological changes (Fowler 1999, Lord *et al* 2001). Therefore, while this species during incubation rarely left their egg for very long (if at all), and thus the egg was not subjected to an increased risk of predation, heating or cooling, disturbance was probably not without impact, as prolonged physiological stress has been shown to have a negative impact in some wild animals (Fowler 1999), and may contribute to lower productivity in disturbed breeding seabird colonies (examples include studies by Rodway and Montevecchi 1996, Giese 1996, Fowler 1999, Leseberg *et al* 2000).

6.2.3 Short-term increases in tolerance

6.2.3.1 Australian Pelicans

Australian Pelicans at both early and late stages of incubation clearly exhibited a steady decrease in PFD's over the course of experimentation (Figure 5.1.7). Reductions in relaxation times for Pelicans during a later stage of incubation also indicate that short-term habituation is occurring. The reduction in relaxation time in late nesting Pelicans may indicate that internalised stress is also decreasing over successive approaches as the Pelicans 'learn' that the *approachers'* activities are relatively benign, however the decrease was arguably minimal (see Figure 5.1.9) and thus does not strongly support this theory. Additionally, behaviour recorded after a disturbance did not decrease to a large extent; however this behaviour may not have represented displacement behaviour as a direct result of human disturbance but may have been due to increased stimulation and activity within the colony.

However Pelicans at an early stage of incubation were found to respond quite differently in that relaxation times increased slightly over successive approaches and they did not allow as close an approach.

The implications of these findings in relation to the total disturbance caused through approach is significant, for while PFD's may decrease rapidly and the colony allow a closer approach by a human, individuals may still endure negative impacts (see Section 2.3.3) from this closeness, displayed in displacement behaviour and relaxation times, which do not decrease at the same extent and at an early stage of incubation, and may actually increase with successive approaches.

6.2.3.2 Greater Crested Terns

Short-term habituation was evident at both early and late stages of incubation, although occurred to a greater extent at a late stage of incubation, probably facilitated both by an increase in site attachment over time spent incubating and the lack of pre-breeders that contributed to up-flight in breeders during an early stage of incubation.

A strong, positive linear relationship was found between PFD's and relaxation times in the later colony (the closer the approach to the breeding colony, the shorter the time taken to return to normal behaviour). This result has enormous implications for understanding the capacity to which this species is able to habituate to human approach, as it indicates that this species has not allowed a closer approach at the expense of internalised conflict (physiological stress), as may be the case in Pelicans and Brown Noddies, in that both PFD's and relaxation times are indicating similar changes in tolerance over a relatively short period of time.

6.2.3.3 Brown Noddies

Results did not show comprehensively whether habituation might have been occurring within this species due to relatively small samples taken from different parts of the colony, which was done to reduce negative effects of disturbance. However a decrease in the relaxation times of breeders from the 20/12/03 may indicate that short-term habituation is possible.

Furthermore, anecdotal evidence suggests that this population has habituated to researcher activity over a number of years, as chicks that have grown up with researcher contact have come back to the same place to breed themselves (ie: they are highly philopatric) and are more aggressive towards intruders than other populations of the same species that have had less contact with humans (Nic Dunlop pers comm). This behaviour is thought to be facilitated by their high site fidelity and few mammal-related anti-predator strategies (Nic Dunlop pers comm.).

6.3 Management Implications and Recommendations

6.3.1 Australian Pelican- Penguin Island

Australian Pelicans nest in multiple colonies (they arrive in waves throughout the year) on the northern and southern-most tips of Penguin Island and breed throughout the year (Figure 3.5, Nic Dunlop pers comm.). These colonies arrived after the addition of walkways on the island, and the subsequent confinement of visitors to the boardwalks and beaches has likely influenced this species' ability to colonise and breed on the island.

Results presented in Chapter 5 indicate that the Australian Pelican can be sensitive to human approach, particularly with respect to the length of relaxation times and intensity of displacement behaviour these colonies experience. Penguin Island's intensive visitation regime during the summer months often results in the Pelican colonies experiencing frequent disturbances throughout this time in the form of human intrusions into the colonies (particularly the northern colony which is more visual and accessible from the walkways) and close approaches via the cliffs (Terry Goodlich pers comm.).

The following management recommendations are suggested to minimise human disturbance to the two Pelican breeding colonies on Penguin Island:

6.3.1.1 Restriction of access

1. Maintain control of human access via walkways.

Several studies stress the importance of predictability of movement for minimising disturbance and facilitating habituation (examples include Burger 1981, Keller 1989, Dunlop and Rippey 2001). CALM should continue to ensure visitor movements are contained, ensuring predictable human behaviour. The two colonies do not appear to react to visitor movements when restricted to paths, although an increase in general vigilance has been observed in Pelicans when visitors approach the lookouts on either end of the island after a long period of low visitor activity (Figure 3.5). This is not thought to have any significant effect on the breeding success of either colony.

2. Restrict access to Australian Pelicans particularly during courting, early incubation periods.

Several studies state that impacts of human disturbance to breeding seabirds are likely to be more severe early on in the breeding season (for example Erwin 1989, Rodway and Montevecchi 1996). This is due to the increased likelihood of temporary or permanent site abandonment (Dunlop 1996, Rodway and Montevecchi 1996, Blackmer *et al* 2004). Results supporting these findings indicate that Australian Pelicans on Penguin Island at an early stage of incubation were found to be less tolerant than those at a later stage in that they could not be approached as closely without initiating flight responses. The temporary closure of walkways or paths (particularly the northern lookout) may be considered by managers during early stages of incubation in this species.

However approach to colonies when juveniles of 3 weeks to 3 months are present has previously caused considerable disturbance, as Pelicans do not learn to fly until they are 3 months old (Johnsgard 1993) and have been known to leap from the cliffs at the northern end of Penguin Island when approached (Terry Goodlich pers comm.). A report by Anderson and Keith (1980) on Brown Pelicans supports this anecdotal evidence, where mobile juveniles attempt to fly away when disturbed and are often entangled in bushes or drowned.

3. Management to buffer current breeding colonies from human disturbance.

In comparison with other research, Australian Pelicans on Penguin Island were shown to be more tolerant to human disturbance than other Pelican species. Literature concerning researcher approach to American White Pelican (*Pelecanus erythrorhynchos*) and Californian Brown Pelican colonies indicates that pelicaniformes are in general highly susceptible to human approach and react at much larger distances than those on Penguin Island during their breeding seasons (Kury and Gochfeld 1975, Anderson and Keith 1980, Anderson 1988). The fact that this species has chosen to nest in two colonies on an island that receives well over 80,000 visitors annually, is itself information that contributes to a better understanding of pelicaniform behaviour.

A Critical Approach Distance (CAD) of 28 meters is recommended for Australian Pelicans on Penguin Island at a late stage of incubation (~ 1 month) and 42 meters for an early stage (<1 week). These critical distances are based upon the largest PFD recorded at each stage of incubation. The greatest distance is important to consider as most human disturbances occur in an irregular fashion and do not mimic the experimental approach-retreat sequence, thus habituation should not become a factor in establishing CAD’s.

It is also important to note that Pelicans at an early phase of incubation react to human approach over a greater distance range than do those at a later stage (Figure 6.1). The effects of length of time that birds are affected and the intensity of the response may have different impacts upon the physiology of Australian Pelicans. It may therefore be prudent for managers to be generous with CAD’s and setback distances as it is likely that hormonal and nervous responses are elicited at greater distances than are behavioural responses (Lord *et al* 2001).

6.3.1.2 Monitor and manage human activity

4. Ensure the presence of a ranger during abalone fishing mornings.

A high level of human disturbance has been observed and is known to occur during abalone fishing mornings, where fishers often climb the cliffs at the northern and southern ends of the island rather than wade back to the eastern beach from the outer reefs. These people have been observed to walk through the Pelican colonies on their way back to the pathways, causing a significant disturbance. It is recommended that rangers are present during these times to ensure that access is restricted in accordance with Regulations under the CALM Act 1984 and the Wildlife Conservation Act 1950.

5. Use of signage and educational material on Penguin Island

While signage already exists at the end of the northern walkway and at the northern end of the western beach, more comprehensive and interpretative educational material concerning the Pelican breeding colonies and what happens when they are disturbed could be placed on the cliffs to the east and west of both colonies or be made immediately available to visitors at the ‘Penguin Experience’ (see Appendix 3).

6.3.2 Greater Crested Tern- Rottnest Island

Greater Crested Terns respond to predators through synchronizing their breeding attempts, nesting very close together and deserting a breeding attempt if sufficiently disturbed (Dunlop 1986, Dunlop 1987). Additionally, Rodgers and Smith (1995) state that nesting terns may be more sensitive to human disturbance than other colonial waterbirds as they exhibit initial mass up-flight. These anti-predator strategies affect the way in which humans can successfully manage this species for conservation and recreational purposes.

6.3.2.1 Restriction of access

1. Maintain control of human access to the lake reserve.

Herschell Lake forms a natural protective barrier from human intervention and disturbance of the breeding colony for much of the year, however dry conditions allow easy access from the road (Figure 3.10). There does not appear to be any adverse behavioural response from the colony to people using the roads and adjacent shoreline and it is recommended that the restriction of access into the lake reserve be maintained, at its current distance of approximately 200 meters, to minimise disturbance and its potential impacts.

2. Management to buffer current breeding colonies from human disturbance.

A Critical Approach Distance (CAD) of 13 meters is recommended for Crested Terns at an early stage of incubation and 52 meters at a late stage. As with Australian Pelicans, these distances are based upon the greatest PFD for early and late incubation phases. The peak of 123 meters was not used as this approach resulted in up-flight and as it is thought that silver gull activity was the cause of this flushing.

In the case of the early terns, it was necessary to consider the presence of pre-breeders, as these birds flushed at greater distances than did the nesting birds on their own and further, caused the flushing of nesters. Gull alarm calls may also initiate the flushing of an early colony, and thus CAD's may change depending upon other species present.

6.3.3 Brown Noddy- Lancelin Island

Results presented in Section 5.3 suggest that this species has a very short CAD (2 meters), which is likely due to their largely pelagic lifecycle and few anti-predator strategies concerning mammals (Dunlop and Rippey 2001). Yet an investigation into the period taken to return to normal behaviour strongly suggested that CAD's may need to be based upon an understanding of displacement behaviour, return and relaxation times, as well as on the initial behavioural response to approach.

The Brown Noddy colony on Lancelin Island is highly accessible from the western beach and accessible from the eastern beach if people choose to ignore the signage and stray from the walkway. Therefore people can approach this colony very closely often without initiating an up-flight response, as can be seen from Chapter 5.3.5.

However there is the potential for physiological impacts to be occurring at such close distances, without an intruder being aware that they are causing harm.

Therefore, the following management recommendation is suggested to minimise the potential for human disturbance to this colony.

6.3.3.1 Restrict Access

1. Restrict access to the Brown Noddy colony during breeding.

Although Brown Noddies only occupy Lancelin Island between October and February annually, access to all vegetated parts of the island remains restricted year-round under the CALM Act 1984. Results of the focal animal sampling suggested that Brown Noddies did not respond to human approach until the *approacher* was within 2 meters of the target individual. However relaxation times often rose to more that 4 minutes. Relaxation times are perhaps more relevant as an indicator of disturbance when humans can get very close to breeding seabirds without them flying away.

Therefore, during the nesting season, a recommended buffer/setback distance of at least 5 meters should be applied to compensate for the high tolerance of this species to human approach and should ensure that both breeders and pre-breeders are not disturbed as a result of human activity. This will only apply to the area of beach and water adjacent to the colony, as most edges of the colony back onto an area of the nature reserve where no access is granted (see Figure 3.8).

6.3.3.2 Monitor and manage human activity

2. Increase signage, educating visitors on the importance of this breeding colony on the eastern and western beaches.

As mentioned in Chapter 3, this colony of Brown Noddies is particularly important scientifically and for conservation purposes, as it may well currently represent the southern-most breeding colony of this species worldwide and is important for scientific research regarding oceanic climate change.

Sign-posting the beaches would inform visitors of the importance of this breeding colony and educate them on the need to remain at a distance (the colony can be observed with no impact on the birds from the walkway or the western beach) (see Appendix 4).

3. Enlist community beach wardens during the busy summer months to ensure visitor activities remain compatible with the objectives of a nature reserve.

Between December and February visitation to Lancelin Island can reach up to 150 people at a time (Nic Dunlop pers. comm). This coincides with the breeding seasons for several seabird species besides the Brown Noddy (for example Fairy Terns). In partnership with CALM, a community volunteer beach warden present on the island during peak visiting times would ensure that visitor activities do not disturb breeding seabirds by educating and advising people of unsuitable behaviour and acting as a direct point of contact with the local ranger.

6.3.4 Generic Management Recommendations for Seabird Breeding Islands

6.3.4.1 Mapping species' habitat, CAD's and inter-visibility

Before any type of human access arrangements are made to a seabird breeding island, an assessment of topography, seabird breeding habitat/current seabird distribution and CAD's of breeding seabirds should first be conducted to determine access restrictions and limitations.

Several mechanisms for establishing setback distances between birds and humans have been suggested. For example, Rodgers and Smith (1995) suggest the use of a model based upon the mean FID and an addition of 40 meters. Giese (1998) suggests a minimum separation distance between humans and breeding Adelie Penguins based upon the distance at which no significant behavioural change was observed.

Ronconi *et al* (2002) however recommend that setback distances be calculated as the sum of approach (flushing) distances and the distance that Black Guillemots forage from the shoreline. In this way a buffer would surround all the known foraging areas of Black Guillemots in the Bay of Fundy, Canada.

A similar method involving the exclusion of nesting habitat rather than foraging habitat is thought to be relevant for Australian Pelicans, Greater Crested Terns and Brown Noddies nesting at different locations to those dealt with here. For each species, the CAD for the most sensitive stage of the breeding season (nest building and early incubation) may be added onto this boundary to create a buffer. For example, if the species in question was the Australian Pelican, an additional 42 meters would be added onto the boundaries of its preferred breeding locations. Therefore, providing the birds do not choose to nest on the very edge of their breeding habitat, there will be a distance greater than their CAD available between the breeding colony and nearest human activity (Appendix 5).

Additionally, topography affects CAD's in that the visibility of an *approacher* plays a key role in the behavioural response of the target bird (Erwin 1989, Richardson and Miller 1997, Ikuta and Blumstein 2003).

Visual barriers may be utilized to further reduce disturbance to breeding seabirds and to allow humans to approach breeding seabird colonies to a closer extent (Sekercioglu 2002). They may therefore be considered as a management tool to reduce human-seabird interactions where an optimal approach buffer cannot be implemented (Rodgers and Smith 1997).

6.3.4.2 Habituation as a management tool

Results have shown that Crested Terns and Australian Pelicans at both stages of incubation exhibit evidence of short-term habituation and anecdotal evident suggests that Brown Noddies are also capable of habituating to human activity. It may therefore be possible and desirable for managers to facilitate habituation in these species in other locations. It is not recommended that human activity encroach within the recommended setback distances, particularly for early nesters, as frequent human activity within this distance can lead to site desertion (Walker 1991, Hockin *et al* 1992).

Habituation is thought best achieved through encouraging predictable human behaviour (for example through the use of walkways), maintaining adequate setback distances and by ensuring all interactions are benign (Keller 1989, Dunlop 1996, Dunlop and Rippey 2001, Ikuta and Blumstein 2003).

6.3.4.3 Monitoring as a management tool

It is important to monitor whether CAD’s are increasing or decreasing. A decrease in the distance between human activity and nesting seabirds will often signify an increase in tolerance in the species, whereas an increase may mean that initial buffers/setback distances were not large enough to minimise negative impacts to the breeding colony.

Monitoring of other seabird behaviour such as displacement behaviour and relaxation or return times will give an indication of the relative impact human activity may be having on a breeding colony.

6.4 Relevance to Other Studies and Opportunities for Further Research

Several studies emphasise the role of the stage of the breeding season in influencing CAD’s or disturbance effects in waterbird species (examples include Anderson and Keith 1980, Erwin 1989, Hockin *et al* 1992, Rodway and Montevecchi 1996, Bolduc and Guillemette 2003). It is generally accepted by these authors that disturbance during courtship or nest-building requires larger CAD’s than disturbance during late incubation or chick-rearing stages. Rodway and Montevecchi (1996) and Bolduc and

Guillemette (2003) also found that disturbance during the earlier stages of incubation had a greater effect upon nesting and breeding success than did disturbance later in the incubation or chick-rearing cycles.

These findings are supported by results presented in Chapter 5 which found a greater initial behavioural response to human approach recorded at earlier stages rather than at later stages of incubation for all three species tested (responses included mass up-flight and higher PFD's). However, these results also revealed that birds during later stages of incubation may experience greater physiological responses directly after a disturbance than birds at an earlier stage, signalled through the longer relaxation times and increased displacement behaviour. This conclusion is based upon evidence that displacement behaviour is often associated with internal conflict and consequential physiological changes such as increased heart rate and elevated corticosterone levels, resulting in increased energy costs to the disturbed birds (Manning 1972, Giese 1998, Lord *et al* 2001).

Birds at a late stage of incubation experience increased displacement as they are more highly site attached and suffer greater 'stress' through opposing tendencies (flight or incubation versus site defence) which is then transferred to external/behavioural changes (Manning 1972, Lord *et al* 2001). Therefore behavioural cues such as the intensity of displacement behaviours and length of relaxation times are important factors in determining some of the impacts caused through human disturbance to breeding seabird colonies.

These findings are important to consider when estimating critical approach distances for waterbird species. Historically, most literature has measured the distance at which up-flight or alert behaviour is first recorded in a breeding or feeding colony (examples include Cooke 1980, Burger and Gochfeld 1991, Rodgers and Smith 1997, Fernandez-Juricic *et al* 2001). However, this study shows that the initial response distance is only part of the effects of disturbance undergone by breeding seabirds, and without taking displacement behaviour into account, potentially harmful effects could still be occurring at ‘optimal’ approach distances designated by wildlife managers.

A review of existing literature revealed that most habituation studies compare responses to disturbance over different locations and visitation regimes (examples include Cooke 1980, Keller 1989, Dunlop 1996, Lord *et al* 2001, Gyuris 2004). While such studies are useful in relating habituation to disturbance types, they do not systematically show habituation occurring in seabird or waterbird species, but instead indicate differences in tolerance between colonies (which could be a function of other site-specific factors as well as human activity).

Nisbet (2000) states that “proof of habituation requires sequential measurements of tolerance within the same individuals or groups”. Results presented in Chapter 5 clearly show a gradual change in tolerance as a direct result of a series of approaches towards the same group of birds. The results therefore show habituation occurring during the period of approach experiments (habituation being defined as ‘the relatively persistent waning of a response as a result of repeated stimulation which is not followed by any kind of reinforcement’). However, this research lacks the comparison of responses of the same species over different visitation (or disturbance) regimes, which was simply a limitation of this study in terms of time.

Another limitation was that the assumed physiological effects of disturbance (such as increased heart rate) were not investigated as part of this research. So while Pelicans and Crested Terns were shown to actively habituate to a repetitive, benign stimulus, potentially harmful physiological responses (such as an elevated heart rate) may have been occurring, and could not be recorded without noticeable behavioural cues (Fowler 1999, Lord *et al* 2001). Further study on the linkages between behaviour and physiology in these species would be useful in order to improve the utility of behavioural research.

It is therefore recommended that if habituation of these breeding colonies is desired by managers, frequent, regular and predictable patterns of human behaviour should be established, (Dunlop and Rippey 2001) encouraging breeding colonies to gradually habituate to human activity, without humans encroaching upon a breeding colony. Habituation should not be used as an argument to more closely approach a breeding seabird colony however (WBM Oceanics and Claridge 1997), as several studies caution that a decrease in behavioural response to disturbance does not necessarily coincide with a decrease in physiological response (Burger and Gochfeld 1993, Giese 1996, Lord *et al* 1997, Fowler 1999, Gill *et al* 2001). However if breeding seabirds encroach upon pathways or walkways (such as with Bridled Terns on Penguin Island) we may assume that no ill effects are occurring.

This research was aimed at developing site-specific guidelines for three species of seabird on three island settings off the coast of Western Australia, with respect to minimising visitor disturbances. However the findings from this study have further implications for developing tourism industries around breeding seabird colonies, where similar considerations should be made regarding approach distances, buffer zones and the relevance of displacement behaviour and relaxation time. Additionally, this model for behavioural research can be used to predict or estimate impacts in cases where nest checks are not feasible or desired.

As previously mentioned in Chapter 2, caution should be used when planning for visitor viewing or entry into seabird breeding areas as CAD's are not fixed but vary depending upon several factors (listed previously in Section 2.1). This study has shown how responses to human approach change between species, stages of the breeding season and over time from short-term increases in tolerance. These results and recommendations may be applied directly to Australian Pelicans, Greater Crested Terns and Brown Noddies on Penguin, Rottnest and Lancelin Islands but also have relevance for other breeding populations.

7. CONCLUSION

Increasingly, seabirds nesting on islands off the south western coast of Western Australia are being exposed to human activity, through rising numbers of people travelling to these small, nearshore islands for the purposes of tourism and recreation. These escalating numbers raise questions about the effect human disturbance may have on seabird breeding behaviour, and ultimately on the breeding success of nesting colonies.

This thesis examined the short-term changes in behaviour of Australian Pelicans nesting on Penguin Island, Greater Crested Terns on Rottnest Island and Brown Noddies on Lancelin Island when approached by a human walking in a straight line towards nesting individuals. Findings were that:

1. Responses differed between species, probably due to the particular anti-predator strategies attributed to each,
2. Responses differed between phases of the nesting cycle, probably due to increasing site attachment over time, and
3. Repeated human approaches were shown to cause a short-term increase in tolerance in Australian Pelicans and Greater Crested Terns and to a lesser extent Brown Noddies.

Results presented in Chapter 5 suggest that CAD's are a species-specific trait (supported by Blumstein *et al* 2003) and should be investigated for the most sensitive phase of the breeding cycle for each species. An understanding of displacement behaviour and relaxation times are also important considerations when determining species' CAD's, as lengthened return times and relaxation times additionally have implications for predation, egg heating or cooling and natural incubation or parenting behaviour (Keller 1989, Henson and Grant 1991, Burger and Gochfeld 1994).

Some internalised stress may have occurred after successive approaches in Australian Pelicans and Brown Noddies as relaxation times were not found to significantly decrease. Gill et al (2001) and Lord *et al* (2001) warn that physiological impacts may be occurring even when birds allow a closer approach by humans. However Crested Terns during late incubation phase were found to habituate to such an extent that there was probably no significant internalised stress as a result of repeated approaches.

Therefore a combination of pre-flight initiation distances (PFD's) and relaxation times are thought to be the most appropriate mechanisms with which to determine the CAD's of these seabird species, particularly for very tolerant species such as Brown Noddies, as relaxation time becomes a significant factor when external responses are minimal.

The challenge for managers of seabird breeding islands is to establish appropriate setback distances (buffers) based upon the CAD's and preferred breeding habitat of each species, that do not impact negatively on breeding seabirds, but that allow equitable access and maximum educational benefit and enjoyment by visitors. Monitoring of the change in CAD's will provide an understanding of the impacts human visitation has on breeding seabirds.

For those islands that already receive large numbers of visitors such as Penguin, Rottnest and Lancelin Islands, the management recommendations listed in the discussion may be applied with respect to Australian Pelicans, Crested Terns and Brown Noddies.

In summation, behavioural research can make a significant contribution to the database on impacts of human disturbance to seabird breeding colonies, and additionally requires a less intrusive approach than traditional studies that involve bird and egg handling. Furthermore, it is important to monitor not just the behaviour during a disturbance and the distances at which individuals react to human approach, but also behavioural cues after a disturbance, and the time taken to return to normal incubating or parenting behaviour.

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9. APPENDICES

Appendix 1- Field Work Data Sheet

Date ________________________________ **Code**__________________

Time of day ________________________(Species: day: approach no.)

Species______________________________

Breeding Season- **early** **late**

Behavioual Events

H= Head turn	**WL**= Wing lift	**Wk**= Walk	**Y**= Yawn
P= Preen	**F**= Fly away	**A**= Alarm Call	**AL**= Alert Posture
Pwn/e= Play with nest/egg Posture		**S**= Shift	**HU**= Head Up
		HD= Head Down Posture	

Approach Experiment

DISTANCE (m)	BEHAVIOUR
100-90	
90-80	
80-70	
70-60	
60-50	
50-40	
40-30	
30-20	
20-10	
10-0	

Return Time- record the behaviour of individual birds for **2 minutes**.

TIME (m)	**BEHAVIOUR and NOTES-** Time taken to return to normal behavioural patterns
2	
4	
6	
8	
10	
12	
14	
16	
18	
20	
22	
24	
26	
28	
30	

Appendix 2- "Before and After" Observations

Date__________________
Species_____________________

Before **(time)**__________ After **(time)**
____

TIME (m)	BEHAVIOUR and NOTES	TIME (m)	BEHAVIOUR and NOTES
2		2	
4		4	
6		6	
8		8	
10		10	
12		12	
14		14	
16		16	
18		18	
20		20	

Appendix 3- Interpretive material on the Australian Pelican breeding colonies

Penguin Island is home to one of the few known breeding colonies of Australian Pelicans on Western Australia's coastline. These birds were thought to have moved from the Peel Estuary after a low-flying plane disturbed the colony. They first moved to Seal Island and then onto the northern end of Penguin Island in 1998. In 2003 they began to breed on the southern end of the island for the first time.

Recent research has found that Australian Pelicans breeding on Penguin Island can be viewed much more closely than other breeding Pelican species around the world. However, Pelicans can suffer negative impacts if they are approached too closely. These can include: less time spent incubating or feeding their young, predation of eggs and young, trampling and crushing of the young pelicans by the adults, entanglement or drowning of young as they try to escape and even the complete desertion of their breeding site.

The Pelican breeding colonies should not be approached any closer than the paths and look-outs allow. By maintaining regular patterns of behaviour through the use of the walkways we may be able to encourage them to slowly move their nest sites closer to us! So please refrain from climbing on the cliffs around the Pelican breeding colonies, not only for your own safety, but to ensure the Pelicans remain breeding at Penguin Island where we can all enjoy a close-up view of their life.

Appendix 4- Interpretive signage on the breeding seabirds of Lancelin Island, with particular reference to the Brown Noddy

Sign 1

Lancelin Island is an important reserve for between 12-18 species of breeding seabirds. The seabirds that nest here are a mixture of temperate and tropical species. The high number of tropical terns that inhabit the island is a result of the warm Leeuwin Current, which brings tropical prey species southward. One species that has recently moved southward from the equator to take advantage of this shift in prey distribution is the Brown (Common) Noddy (*Anous stolidus*).

The Brown Noddy was first detected on Lancelin Island in 1992 as a colony of five pairs. Now the island is host to approximately 960 breeding pairs. The Brown Noddy additionally nests in several northern locations throughout Australia and is common throughout the tropics of the world. The population at Lancelin Island is ecologically important as it is the southern-most known population of this species in the world and therefore has considerable conservation and research significance.

Sign 2

Common Noddy breeding colony (October-February)

Please help protect the breeding seabirds of Lancelin Island by:

- No dogs
- No kites
- Remain on the beaches and walkways

Appendix 5- An example of how to plan for human access on seabird breeding islands