# CHAPTER 1
General introduction

## 1.1 Shorebirds in Australia

Shorebirds, sometimes referred to as waders, are birds that rely on coastal beaches, shorelines, estuaries and mudflats, or inland lakes, lagoons and the like for part of, and in some cases all of, their daily and annual requirements, i.e. food and shelter, breeding habitat. They are of the suborder Charadrii and include the curlews, snipe, plovers, sandpipers, stilts, oystercatchers and a number of other species, making up a diverse group of birds.

Within Australia, shorebirds account for 10% of all bird species (Lane 1987) and in New South Wales (NSW), this figure increases marginally to 11% (Smith 1991). Of these shorebirds, 45% rely exclusively on coastal habitat (Smith 1991). The majority, however, are either migratory or vagrant species, leaving only five resident species that will permanently inhabit coastal shorelines/beaches within Australia. Australian resident shorebirds include the Beach Stone-curlew (*Esacus neglectus*), Hooded Plover (*Charadrius rubricollis*), Red-capped Plover (*Charadrius ruficapillus*), Australian Pied Oystercatcher (*Haematopus longirostris*) and Sooty Oystercatcher (*Haematopus fuliginosus*) (Smith 1991, Priest *et al.* 2002). These species are generally classified as 'beach-nesting', nesting on sandy ocean beaches, sand spits and sand islands within estuaries. However, the Sooty Oystercatcher is an island-nesting species, using rocky shores of near- and offshore islands rather than sandy beaches. The plovers may also nest by inland salt lakes.

Shorebirds around the globe have become increasingly threatened with the pressure of predation, competition, human encroachment and disturbance and global warming. Populations of birds breeding in coastal areas which also support a burgeoning human population are under the highest threat. In Australia, all resident beach nesting birds, with the exception of the Red-capped Plover, are listed in the NSW *Threatened Species Conservation Act* (1995) and are regarded as either endangered, as in the case of the Beach Stone-curlew and Hooded Plover (Schedule 1), or vulnerable, as is the case for the Australian Pied and Sooty Oystercatchers (Schedule 2). Consequently, there is much concern over the decline of populations of these species (Lane 1987, Smith 1990, 1991, Newman 1991, Watkins 1993, Weston 2001, Priest *et al.* 2002, Weston and Elgar 2007). The Hooded Plover is restricted to the southern areas of Australia, thus occurs outside the range of this study, while the Beach Stone-curlew remains in few locations at all in NSW (estimate of 10-13 birds Smith 1991 c.f.

Rohweder 2003). Hence, the Australian Pied Oystercatcher and ecologically similar Sooty Oystercatcher were chosen for study and are the species of focus for this thesis.

While most oystercatcher species breed in the southern hemisphere, most research has actually taken place on species occurring in the northern hemisphere, with the Eurasian Oystercatcher (*H. ostralegus*) among the most studied shorebird in the world (Hockey 1996). Unlike such international counterparts, a paucity of information exists on the basic biology and ecology of the Australian oystercatchers (Lane 1987, Hockey 1996). Work that has been undertaken on Australian oystercatchers has generally been restricted to the southern temperate regions, focusing on counts, movements and measurements (Victorian Wader Study Group (VWSG) and Australasian Wader Study Group (AWSG) unpublished data, Wakefield 1988, Weston *et al.* 1995, Minton 1997, Kraajijeveld-Smit *et al.* 2001, 2004), or limited studies on habitat use (Lauro and Nol 1995a), foraging ecology (Considine 1979, Chafer 1993, Lauro and Nol 1995b, Minton 1998, 1999) and breeding biology (Newman 1983, 1986, 1992, Newman and Park 1992, 1993) in regions where both species are considered to have a secure status.

While this information has provided some insight into distribution and extent of movements and life history attributes, much information may not be applicable to other regions of the country. In NSW, where both species are considered vulnerable, basic information is lacking, such as abundance, distributions, population structure, life histories, ecology and threatening processes (Lane 1987). Furthermore, while reports suggest that human disturbance and other factors contribute to failed reproduction, the actual impacts have rarely been documented and little is known about the impact that disturbance has not only on reproductive success but also on breeding behaviour (see Weston and Elgar 2005, 2007). Similarly, while the foraging ecology and behaviour of northern hemisphere oystercatchers has been studied in much detail (Goss-Custard *et al.* 1977, 1995, 1996a, 1996b, 1996c, 1996d, 2004, Hulscher 1996, Zwarts *et al.* 1996a, 1996b, 1996c, West *et al.* 2002) few Australian studies have focused in detail on this area. With such different environments, prey species and prey densities in southern hemisphere habitats, and little base-line data available on prey populations and their life histories (Jones and Short 1995, Jones *et al.* 2004, Hacking 2007), there is little basis for attempting to determine the impact that increased disturbance, changes in climate or reductions in prey density may have on oystercatcher populations.

## 1.2 The Oystercatchers

### *1.2.1 Taxonomy*

Oystercatchers occur on temperate and tropical coastlines almost worldwide, occurring on every continent except for Antarctica (Marchant and Higgins 1993). While there is debate about the taxonomy and division of subspecies, Hockey (1996) has suggested that world wide there are around 16 taxa of the family Haematopodidae. Based on widespread distribution patterns he suggests the following grouping of species: the nearctic and neotropical group or region, including: 1) Black Oystercatcher *H. bachmani;* 2) Blackish Oystercatcher *H. ater*; 3) Magellanic Oystercatcher *H. leucopodus*; 4) American Oystercatcher *H. p. palliatus*; and 5) American Oystercatcher (subspecies) *H. p. galapagensis*; The palaearctic region, including: 6) Eurasian Oystercatcher *H. o. ostralegus*; 7 and 8) Eurasian Oystercatcher subspecies *H. o. longipes and H. o. osculans*; and the likely extinct 9) Canarian Black Oystercatcher *H. meadewaldoi*; the Afrotropical region of which only one species occurs, 10) African Black Oystercatcher *H. moquini*; and finally, the Australasian region, including: 11) Sooty Oystercatcher *H. fuliginosus fuliginosus*; 12) Sooty Oystercatcher (northern subspecies) *H. f. ophthalmicus*; 13) Variable Oystercatcher *H. unicolor*; 14) Australian Pied Oystercatcher *H. longirostris*; 15) Chatham Island Oystercatcher *H. chathamensis*; and 16) another Eurasian Oystercatcher subspecies *H. o. finschi.*

However, recent investigation using genetic analysis has now stirred further debate, suggesting that hybridisation between some species has occurred and that, on the basis of DNA bar-coding, only nine or ten species should be recognised. Hybridisation has apparently occurred between some of the species within the Australasian group and some also within the Eurasian group (Baker and Tavares 2007), although further research is required.

### *1.2.2 Physical description*

Generally, there are two morphs of oystercatcher, the black and the pied (black and white). However, one species, *H. unicolor*, occurring in New Zealand, is polymorphic, ranging in colour morph from black to pied through intermediate (dull mottled) variations. Oystercatchers form a rather homogeneous group of birds, with little variation in size, shape, appearance, behaviour or ecology (Hockey 1996). All species are large (40-49 cm long) heavily built birds, having sturdy legs and a long straight strong bill that is specialised for dealing with both hard bodied and soft bodied prey (Plate 1.1a and b). The legs, bill and eye ring of adults are a bright scarlet-red-orange colour (Marchant and Higgins 1993). However, sexual dimorphism is evident, with females being heavier, possessing longer more slender bills and slightly longer wings than males (Kraajijeveld-Smit *et al.* 2001, 2004, Hansen *et al.* 2009). Australian Pied Oystercatcher chicks have downy white under-parts and motley buff/sandy/grey upperparts, breast, head, neck and upper tail (Plate 1.1c). The bill, legs and eye ring are grey/black in colour and the bill is quite short. As they progress to immature birds, the bill, eye ring and legs become more similar to that of adults (Plate 1.1d), however, the legs remain grey for some time and the edges of their feathers are still motley. Sooty Oystercatcher chicks are similar. However, they have grey/black down on both the upper and under-parts. Both immature oystercatchers and adults undergo an annual moult during spring and summer, which lasts approximately 120-150 days, although moult period varies regionally (Kraajijeveld-Smit *et al.* 2001, 2004). Although very similar, Sooty Oystercatchers are larger and heavier than the Pied (Hansen *et al.* 2009).


**Plate 1.1**: Physical appearance of the a) mature Sooty Oystercatcher, b) mature Australian Pied Oystercatcher, c) Australian Pied Oystercatcher chick (5 days old) and d) immature 6 week old Australian Pied Oystercatcher.

### 1.3 Australian oystercatcher distribution

Australian Pied and Sooty Oystercatchers are coastal residents distributed unevenly around the entire Australian coastline in small numbers, using ocean beaches, estuaries, inlets, near-shore islands, offshore islands, reefs and atolls (Marchant and Higgins 1993). Being marine/coastal species, they are generally restricted to the narrow shoreline of the continent and are rarely seen far from the coast. Although the species are sympatric, the Australian Pied Oystercatcher typically occurs on sandy shores while the Sooty Oystercatcher uses rocky shores.

The range of the Australian Pied Oystercatcher also extends north of Australia, to include southern New Guinea and nearby islands (Lane 1987). Although phenotypically similar, two sub-species[1] of the black form of Australian oystercacters exist (Baker 1977). The northern race, *H. f. ophthalmicus*, extends from Point Cloates on the north-west coast of Western Australia north around to Mackay on the north-east coast of Queensland (QLD) (Figure 1.1). The southern race, *H. f. fuliginosus* (sub-species studied herein), occupies the remaining coastaline of the continent; ranges are discrete and there is no evidence of hybridisation (Hockey 1996). However, there is debate regarding a potential integrade or overlap of range along the western coastline.


**Figure 1.1**: Distribution of the two races of the Sooty Oystercatcher.

[1] The northern race differs from the southern in bill shape and in having a prominent red fleshy orbital ring (McKean 1978).

## 1.4 Oystercatcher habitat use

### *1.4.1 Australian Pied Oystercatcher*

Australian Pied Oystercatchers are sandy shore specialists, with a preference for foraging on soft sediments in which invertebrate prey occur (Lauro and Nol 1995b). Although Australian Pied Oystercatchers use both sandy beaches and sand flats within estuaries as feeding habitat, occupancy may depend on habitat availability and suitability. In Victoria and Tasmania, high numbers of Australian Pied Oystercatchers forage on extensive intertidal estuaries, where they make use of vast tidal mudflats (Lane 1987, A. Harrison pers. obs.). However, in northern NSW and Queensland (QLD) the species utilise ocean beaches, estuaries and occasionally coral cays (Marchant and Higgins 1993, Owner and Rohweder 2003). Although traditionally coastal species, oystercatchers do use inland areas including grassy fields adjacent to the coast and near coastal lakes, for foraging and nesting (Lane 1987, Marchant and Higgins 1993, Minton 1998, 1999). High tide roosts at the water's edge and nests just above the high water mark occur on open sandy spits, dunes, islands within estuaries, on ocean beaches, and also within the sheltered margins of salt marsh, inlets and lagoons (Lane 1987, Marchant and Higgins 1993, Weston 1993). Nests are a simple scrape in the sand, where they may or may not be lined with leaves, pebbles, shells or other debris. Foraging and roosting have also been recorded on rocky shores (Marchant and Higgins 1993).

Sandy beaches, as a whole system, are comprised of dunes, beaches and surf-zones, all of which are governed by the dynamic interchange of sediment (Hacking 2002). Ocean beaches are also "transition zones", in which the upper zone (beach dune) is occupied by terrestrial air breathing animals while the lower (beach, surf zone) is occupied by marine organisms (Creese and Kingsford 1998, Hacking 2002). Oystercatchers feed in the lower zone of the beach, known as the swash or surf zone, where waves interact with beach sediment. This section of the beach is considered to be the sub-aerial beach, beginning with the high tide mark and extending toward the low tide water line (Hacking 2002). Within the sandy substrate a diverse group of invertebrate organisms, known as macrofauna, persist. Typical sandy beach macrofauna include: crustaceans, including various crabs and shrimps; molluscs, including various gastropods and bivalves; and polychaete worms. Unlike prey species of rocky shores, beach fauna generally live within the sand and are not visible from the surface. Prey that are buried in soft sediment usually maintain contact with the surface, which is necessary for feeding, respiration and expelling wastes. Consequently, they leave visible traces, which shorebirds use to locate them (Hulscher 1996).

Intertidal bays, inlets and estuaries are also regulated by tidal sea-water, being exposed for a few hours each tidal cycle. Invertebrate species within the lower reaches (seaward end) of estuaries are generally limited due to lack of oxygen and sediment size, thus, fewer species persist there than on open ocean beaches. Species found within these areas include various crustaceans, (yabbies and crabs), molluscs (small bivalves) and annelids (various small worm species).

### *1.4.2 The Sooty Oystercatcher*

Sooty Oystercatcher habitat is similarly a transition zone between land and sea. The Sooty Oystercatcher is a rocky shore specialist, preferring to forage in the intertidal zone on rock flats and ledges, reef and tidal rock pools (Lane 1987, Hewish 1990, Weston 1993, Lauro and Nol 1995b, Owner and Rohweder 2003), where marine invertebrate prey, including various species of limpet, barnacle, algae, gastropod, sea squirt, urchin etc. are plentiful (Creese and Kingsford 1998). However, this species may also forage on mudflats and has been recorded doing so some distance inland (Schultz 1995), and in some regions (e.g. Victoria) frequently occurs in the company of the Australian Pied Oystercatcher (Marchant and Higgins 1993).

Rocky shore prey species occur on the surface of the substrate, rather than within the sediment. Although they are not sessile, movement is very slow, therefore prey are very visible. However, these prey are generally attached firmly to rock, thus require prising or hammering as a means of loosening and removal before consumption. During the low tide period, the rocky intertidal is also exposed for a few hours, in which time oystercatchers are able to feed. This habitat can range from quite homogeneous flat rocks and boulder fields largely devoid of invertebrates to very steep and complex rock forms. Nesting habitat has also been partitioned between the species.

The Sooty Oystercatcher remains faithful to rocky shores, while nesting on offshore and near-shore rocky islands (Lane 1987, Pringle 1987, Marchant and Higgins 1993, Weston 1993). Generally, nests are placed just above the high water mark, in the upper zones where habitat is almost entirely terrestrial, and a mere scrape is made in the pebbles, or between rocky crevices, where a lining of debris and pebbles may be placed (Marchant and Higgins 1993). Similar to the Australian Pied, the Sooty Oystercatcher is also generally sedentary when breeding. However, they make frequent local movements between island and mainland shores (Lane 1987).

Although the two species have partitioned their use of coastal resources, they do not necessarily exclude one another (Lauro and Nol 1995b), occurring together occasionally along shorelines that exhibit a mixture of both rocky and sandy habitats.

## 1.5 Life history

### *1.5.1 Reproductive biology*

Oystercatchers are long-lived species, with reports and predictions of individuals living for up to 40 years (Ens *et al.* 1996, Hockey 1996). The Australian oystercatchers have been recorded to reach approximately 25 years (G. Clancy pers. comm., Marchant and Higgins 1993). Survivorship of adult oystercatchers is estimated at approximately 90% annually (Newman 1984, 1989, le V. dit Durell 2007). All oystercatchers have delayed breeding, commencing between four and six years of age (Newman 1992, Marchant and Higgins 1993, Ens *et al.* 1996, Hockey 1996).

Oystercatchers are generally monogamous birds that form life-long pair-bonds, although exceptions to this have been observed (Newman 1986, Heg and van Treuren 1998, Totterman and Harrison 2007). Breeding has been recorded from June to September for Australian Pied Oystercatchers of tropical Australia, and between September and December for those in the temperate south (Newman 1992, Lauro and Nol 1993, Marchant and Higgins 1993). Breeding for the Sooty Oystercatcher is also reported to occur from September to January (Marchant and Higgins 1993). Pairs generally attempt to breed annually, although some individuals appear to skip a year occasionally (Schmechel 2001). Australian Pied and Sooty Oystercatchers have been known to interbreed, although this is rare (Pringle 1987).

During breeding, oystercatchers acquire a traditional territory surrounding their nest, which both birds defend vigorously. Defence may involve alarm calls, aggressive attacks or feigning injury depending on the perceived threat. They have strong site fidelity and are generally sedentary while breeding. Oystercatcher pairs may occupy the same territory for up to 20 years (Hockey 1996). Some individuals will continue to defend a territory throughout the year.

Australian Pied Oystercatchers lay two to four eggs, though in most cases there are only two eggs, rarely there are four (Lane 1987, Pringle 1987, Marchant and Higgins 1993). Following nest failure, one to four replacement clutches are laid within a season, occurring two to three weeks following the loss, however, only one brood will be raised per year (Johnsgard 1981, Lane 1987, Newman 1992, Sagar *et al.* 2000, Davis *et al.* 2001, Schmechel

2001). Sooty Oystercatchers lay two or occasionally three eggs. Replacement clutches are also laid, and again, only one brood will be raised per year (Marchant and Higgins 1993, Lauro and Nol 1995a).

Incubation lasts 28-30 days in both species. Both male and female oystercatchers are reported to share in incubation and chick rearing duties. Once chicks hatch they leave the nest within 24 hours. Unlike most other shorebirds, oystercatchers provide parental care to chicks, both parents partaking. Thus, oystercatcher chicks have the benefit of a precocial and altricial upbringing (Lane 1987, Safriel *et al.* 1996, Marchant and Higgins 1993). Being mobile and camouflaged, chicks are able to seek shelter from predators by concealing themselves in rock and sand crevices, wheel tracks on beaches, and beneath/beside vegetation, where they crouch and rely on camouflage (Safriel *et al.* 1996). Young have also been reported to swim and dive beneath the water's surface to avoid danger (Morgan 1994).

Chicks are fed by parents for the first four to five weeks in which time they learn how to search for and handle prey. After this time immature birds generally feed themselves, and have begun to fly short distances. At this time chicks are said to have fledged, however, they remain with their parents who occasionally still feed them for three to five months (Marchant and Higgins 1993). In some cases, nine months post-fledging, immature Australian Pied Oystercatchers have still been observed with parents (A. Harrison pers. obs.). Immature birds are reportedly independent 100-200 days after hatching and are reported to either remain close to natal areas or return to those areas to nest when mature (Hockey *et al.* 2003). On average the Australian Pied Oystercatcher in Tasmania was reported to nest only 5 km from the place of hatching (Newman 1983).

Oystercatchers of the world generally have low breeding success (Hockey 1996, Sagar *et al.* 2000, Davis *et al.* 2001, Schmechel 2001) and although relatively little work has been done on either of the Australian species, apparently Australian Pied Oystercatchers are no exception to this (Newman 1983, Lane 1987, Newman 1992). In a 12-year study Newman (1989) reported that there is also only a 15% probability of a juvenile Australian Pied Oystercatcher surviving to breeding age.

### *1.5.2 Foraging ecology*

Oystercatchers take a wide array of prey, with oystercatcher species varying between soft and hard substratum feeders (Hockey 1996). While a diversity of prey species (up to 52, in African Black Oystercatchers) have been recorded (Hockey and Underhill 1984), generally the diet of soft substratum feeders is dominated by bivalves and polychaetes, and may also consist of crabs, amphipods, echinoderms, ascidians and fish. Hard substratum feeders, on the other hand have diets that are dominated by molluscs such as limpets, gastropods, chitons and mussels (Hockey 1996).

Much of the research on functional response and optimal foraging theory of oystercatchers, including individual prey size selection, prey profitability, search speed, intake rates, seasonal changes in prey preference and differences between the sexes has focused on *H. ostralegus* in the northern hemisphere (Ens *et al.* 1996, Bunskoeke *et al.* 1996, Goss-Custard *et al.* 1996c, 1996d, Hulscher *et al.* 1996, Hulsman *et al.* 1996, Zwarts *et al.* 1996a, 1996b). More recently the focus has shifted to behaviour-based modelling of the impacts of habitat loss and climate change on populations, again for the much studied *H. ostralegus* (Goss-Custard *et al.* 1995, 2003, Stillman *et al.* 2000, 2001, 2002, 2003, 2007, West *et al.* 2002, 2003). In Australia little work has been undertaken on any of these aspects (Lane 1987) and it is only recently that we have begun to examine foraging method and prey selection of both the Australian Pied and Sooty Oystercatchers (Dann 1987, Chafer 1992, 1994, Lauro and Nol 1995b, Owner and Rohweder 2003). Recently, however, such behaviour-based modelling has been applied to the Australian Pied Oystercatcher in Tasmania (Atkinson and Stillman 2008), using detailed foraging data collected by Harrison (2008) and benthic data provided by others (Aquenal 2008).

Like the Eurasian Oystercatcher (Zwarts *et al*. 1996a, 1996b), a large portion of the diet of the Australian Pied Oystercatcher is comprised of bivalves and polychaete worms. In northern NSW the most common bivalve mollusc to be taken is the beach ‘pipi’ *Donax deltoides* (maximum length of 60 mm), which is often abundant in the intertidal zone, found 60-100 mm below the sand surface of many wave exposed (ocean) sandy beaches, from South Australia around to southern Queensland (Saenger and Keyte 1990, Murray-Jones 1999). In other parts of Australia, such as Tasmania, other bivalves, such as *Katelysia* spp. (maximum size approximately 50 mm) also form an important part of the diet (Taylor 1999, A. Harrison unpublished data). Diet of the Sooty Oystercatcher is more varied, with 24 prey species recorded in Victoria (Dann 1987). Prey recorded for the Sooty Oystercatcher include limpet, gastropods, chiton, mussel, bivalves, crabs, barnacles, sea squirts, polychaete worms and amphipods, with species depending upon substrate of foraging habitat (Chafer 1992, 1994, Lauro and Nol 1995b).

Specialisation is known to occur with individuals favouring certain prey sizes and prey species dependent on the harvestability, profitability and digestability of what is available at the time (Goss-Custard and Durell 1983, Ens *et al.* 1996, Zwarts *et al.* 1996).

Shifts in diet, in response to daily and seasonal abundance of prey and in response to the increase of invasive species, are known to occur (Hockey and Underhill 1984, Dann 1987, Hockey 1996, Hulscher 1996, Hockey and van Erokom Schurink 1992). Hence, the diet of a species may vary widely both temporally and spatially. There is also variation between individuals of the same species (for northern hemisphere oystercatchers), in the way in which they search for (pecking, probing, stitching) and deal with their prey (hammering, levering, scissoring, stabbing) (Hulscher 1996). Furthermore, the specialisation adopted by individuals will be adopted by their offspring, as they learn how to forage from their parents (Hulscher 1996). Sexual dimorphism allows for differences between the sexes in prey species taken and methods used. Males, with generally more robust bills, are believed to consume a greater portion of hard bodied prey than females with their longer more slender bills (Lauro and Nol 1995b).

**1.6 Movements and flocking**

Unlike the well studied *H. ostralegus*, Australian Pied and Sooty Oystercatchers are generally not migratory. Dispersal is limited, although daily movement between off-shore islands and mainland foraging habitat is common for Sooty Oystercatchers, and movement between neighbouring estuaries and embayments is common, particularly during winter months, for Australian Pied Oystercatchers (Pringle 1987, Lane 1987). Although sedentary, long distance movements are possible for both species, with occasional records indicating movements over several hundred kilometres. Both the Australian Pied and Sooty Oystercatcher have been recorded to cross the Bass Strait between mainland Australia and Tasmania, and both have had movements of approximately 100-350 km between mainland locations on the east and west coasts (Minton 1991, 1988, Lane 1987, AWSG unpublished data, G. Clancy pers. comm.). The longest movement for the Sooty Oystercatcher, around 500 km, was recorded between the Corner Inlet in Victoria and the south-west coast of Tasmania (Hansen *et al.* in prep). Similarly, the longest record for the Australian Pied is 416 km (Jarman and Keating 2003).

During the non-breeding season (May to August), both species tend to flock with individuals moving together locally, concentrating in traditional roosting sites (Lane 1987). Mixed flocks of Australian Pied and Sooty Oystercatchers do occasionally occur during this period in both sandy and rocky habitats (Pringle 1987). Flocks of up to 100 Australian Pied Oystercatchers have been reported for Victoria and Tasmania (Lane 1987), and large flocks have also been reported for the Sooty Oystercatchers in those regions (Watkins 1993, Hansen *et al.* in prep).

## 1.7 Population estimates and conservation status

### *1.7.1 Population estimates*

The world population of Australian Pied Oystercatchers may be as low as 10,000 – 11,000 individuals (Watkins 1993). However, numbers vary between each of the Australian states with Victoria, Tasmania and South Australia supporting the largest numbers (Watkins 1993). Birds are distributed unevenly throughout each of the states. Key locations accommodating significant numbers include the Corner and Shallow inlets of Victoria (1,300 individuals), the Coorong of South Australia (630), and the Derwent-Pittwater region (570) and the Furneaux Islands (500) of Tasmania (Lane 1987, Watkins 1993, AWSG unpublished data). In those states, along with Western Australia and Queensland, the Australian Pied Oystercatcher population is generally considered stable (Hewish 1990, Watkins 1993, Garnett and Crowley 2000). However, some declines have been noted (Newman 1990) and in Tasmania a decline was forecast (Newman 1991). Numbers of the Australian Pied Oystercatcher in NSW (1,436 km of NSW coastline in total) are comparatively very low, with an estimated a total population of only 250 individuals for that state (Smith 1991, NPWS 2003).

Similarly, the total Sooty Oystercatcher population is quite low with 4,000 individuals estimated for the southern race *H. f. fuliginosus* and a recently updated estimate of 7,500 individuals for the northern race *H. f. opthalmicus* (Delaney and Scott 2006). However, the updated estimate for *H. f. opthalmicus* is quite large compared to the previous estimate of only 1,000 individuals (Watkins 1993), and the reliability of the latter may be low; much of the remote coastline of northern Australia remains to be surveyed closely. As for the Australian Pied Oystercatcher, the Sooty is sparsely distributed with high numbers in a few key locations. Large counts have been reported for the Furneaux Islands of Tasmania (560), Corner and Shallow Inlets (270), Nuytsland Nature Reserve in Western Australia (180), and Murat Bay in South Australia (160) (Drummond 1984, Schulz 1990, Watkins 1993, AWSG unpublished data). Counts from some of these regions fluctuate widely between seasons and annually, however, overall, they appear stable (Hewish 1990). Again, numbers in NSW are comparatively low, with only 250 – 480 individuals reported for the state (Smith 1991, Watkins 1993).

### *1.7.2 Conservation status*

Unsurprisingly, Australian Pied and Sooty Oystercatchers are both listed as vulnerable species in NSW under Schedule 2 of the *Threatened Species Conservation* (TSC) *Act* (1995). The criteria for vulnerable species, as devised by the IUCN (1994), cited by Garnett and Crowley (2000), state that a taxon is *Vulnerable* when it is neither *Critically Endangered* nor *Endangered*, but is facing a high risk of extinction in the wild in the medium-term future. Moreover, vulnerable species are those that are likely to become endangered unless the circumstances and factors threatening their survival or evolutionary development cease to operate.

Following an evaluation of native vertebrates in NSW by the National Parks and Wildlife Service (NPWS), it was determined that both Australian Pied and Sooty Oystercatchers met certain criteria set down by the TSC Act, thus placing them in the vulnerable category. Specific reasons for listing the Australian Pied Oystercatcher include that it: i) has a limited distribution; ii) the state population has been severely reduced; iii) faces severe threatening processes; iv) is an ecological specialist; and v) has poor recovery potential (NPWS 2003a). Similarly, the Sooty Oystercatcher was also listed for these reasons. However, the Sooty population was said to have been reduced to a critical but stable level (NPWS 2003b).

During 2008, information on the Australian Pied Oystercatcher was submitted to the Scientific Committee in support of upgrading the status to endangered in NSW (S. Debus pers. comm.). This is currently under consideration. With such low numbers, the southern subspecies of the Sooty, *H. f. fuliginosus*, could be considered one of the rarest oystercatchers in the world, comparable only to the endangered Chatham Island Oystercatcher (*H. chathamensis*), the near-threatened American Oystercatcher (*H. palliatus*), a species of special concern, and the near-threatened African Black Oystercatcher (*H. moquini*), which all have populations of 5000-10,000 individuals (Schmechel and O'Connor 1999, Toland 1992, Brown *et al.* 2005, Underhill in prep.). However, owing to the paucity of information available on this species, and the widely fluctuating counts reported, a revised assessment is unlikely for the Sooty.

## 1.8 Threatening processes

Species declines in Australian oystercatchers have been attributed to lack of breeding success. Threats to the species include: human disturbance to feeding, roosting and nesting sites; destruction of nests, eggs and chicks by trampling or crushing by humans and dogs;

habitat loss; invasion and predation by foxes, feral and domestic dogs and cats; pollution of coastal areas; increased coastal development; storm damage; changes to hydrological systems; loss of prey resources; and climate change in the long-term (Lane 1987, Smith 1991, Newman 1991, Lauro and Nol 1993, Marchant and Higgins 1993, Watkins 1993, Priest *et al.* 2002, Chambers *et al.* 2005).

### *1.8.1 Increasing human populations and recreational disturbance*

Following the arrival of the first Australians some thousands of years ago, the Australian coast remained undeveloped, and from this time until 1788 when Europeans arrived, little had changed. However, with the spread of European settlement from Sydney along the NSW coast, beaches became 'coastal highways' which were used for transport and travel, thus giving rise to many ports and coastal shipping roads over time. The close association between people and the coast grew and during the early 1900s people had found a new use for beaches: a source of relaxation on their day off, and daylight bathing was permitted for the first time (Short 2000). This close association has become part of Australian life and today Australians remain attracted to coastal areas, to the beach and the surf. However, this association has placed a growing strain on the coastal environment, which continues to increase rapidly.

Of all environments that shorebirds inhabit, the coastal zone is by far the most threatened. Presently, over 85% of the Australian population inhabit the coastal region (within 50 km from the shore), with an amazing 25% of people living within three kilometres of the coast (Priest *et al.* 2002, Australian Bureau of Statistics 2009). Furthermore, this already large percentage is set to increase, as annually more people flock to coastal areas to live and in particular, to holiday during the summer months. With increased habitation of coastal areas there has been an increased demand for access to beaches, for both pedestrian and vehicle use. This flux of people has resulted in intensified human disturbance and associated pressures in some coastal areas, such as NSW beaches, rocky shores and estuaries. Regrettably, this pressure has resulted in the disturbance of both migratory and resident shorebirds, particularly during the vulnerable breeding season when recreation is at its peak during spring and summer months. Consequently, during this important time in the breeding cycle, birds are not only forced to compete for space in what is an already narrow and limited habitat, but they become vulnerable to the effects of various types of human disturbance. Beach nesting birds such as the endangered Little Terns (*Sterna albifrons*), endangered Beach Stone-curlew and vulnerable Australian Pied Oystercatchers are particularly at risk, as are those that utilise the rocky shores such as the Sooty Oystercatcher. Principally, these birds are vulnerable to the effects of human disturbance as they nest just above the high tide mark and often in readily accessible areas to humans (Lane 1987, Smith 1991, Priest *et al.* 2002).

Shorebirds are vulnerable to both direct and indirect effects of human disturbance. Indirect effects of human disturbance include movement such as walking, swimming and sun-baking, also the passing of off-road (4WD) vehicles, which inadvertently disturbs birds while they are feeding, roosting and nesting. This disturbance may result in birds leaving the nest temporarily, exposing eggs to over-heating or cooling, and exposing eggs and chicks to predation by domestic and feral animals, and may result in abandonment of nests (Burger 1981, Burger 1994, Lindberg *et al.* 1998, Dowling and Weston 1999, Ruhlen *et al.* 2003). Such activities also result in less time available for foraging and parenting, which over time result in increased stress and energetic costs to parents, via increased threat avoidance, flight and defence, and displacement (Yalden and Yalden 1990, Burger and Gochfeld 1991, Hockin *et al.* 1992, Burger 1994, Lafferty 2001, Taylor and Knight 2003, McGowan and Simons 2006). Such costs may then impact upon reproductive success, growth and survival of individuals and populations (Smith 1990, Burger 1994, Verhulst *et al.* 2001, West *et al.* 2002, Ruhlen *et al.* 2003, Müller *et al.* 2004, Murison *et al.* 2007, Stillman *et al.* 2007). Unlike migratory species (Gill *et al.* 2001, 2007) or non-breeding residents, coastal breeding residents are restricted to narrow traditional habitats, thus are unable to move to alternative habitat when disrupted. Also given that foraging is dictated by tidal cycles, opportunities for compensating against lost time are minimal. Hence, daily disturbance to local populations of oystercatchers can be more detrimental than habitat loss, industrial development and major shoreline perturbations, with potential to extirpate them (Andres 1999, West *et al.* 2002, Gill *et al.* 2004, Stillman *et al.* 2007). Consequently, shorelines that suffer intense and frequent disturbance generally lack oystercatchers (Burger 1981, Lindberg *et al.* 1998, Andres 1999).

Direct effects include damage caused to feeding, roosting and nesting sites, which may occur as a result of inappropriate use of 4WD vehicles, i.e. driving or parking on fore-dune and high beach zones, or other intentional activities. Direct effects also include destroying nests, eggs and chicks by either trampling or crushing with vehicles which may occur when vehicles are driven through or parked in inappropriate areas such as fore-dunes or by letting dogs off leashes and/or riding horses in inappropriate areas, such as shorebird nesting sites (Priest *et al.* 2002). Regrettably, vehicles also have the potential of directly impacting on birds via colliding with them and killing them (Melvin and Griffin 1994).

Australian Pied Oystercatchers are potentially vulnerable to this activity on all beach zones due to their behaviour. When feeding at the waters edge, birds often have their heads down and tail up and are not vigilant to fast moving threats. Also, when roosting, which they often do in tyre tracks on all beach zones (A. Harrison pers. obs.), birds tuck their bill under their wing and close their eyes and are hence not vigilant to oncoming traffic. Melvin *et al.* (1994) also found that the behaviour of chicks places them at risk of being crushed, as they become moving targets venturing from the fore-dune to the waters edge and due to sheltering in tyre tracks where they are unable to quickly escape oncoming vehicles. Although many shorebird nesting sites in NSW are protected with symbolic fencing and quite large signs explaining that threatened species nest within the area, unfortunately, there have been many instances where people disregard signage and enter such areas, placing breeding birds at risk and forcing them to leave their nests (Melvin *et al.* 1992, A. Harrison pers. obs.).

Increasing pressure for coastal development has also placed coastal dwelling species at risk of habitat loss, either through reclamation of intertidal foraging areas and through associated increases in access to coastal regions and an increase in recreational disturbance that result in a decline in habitat useability (Stillman *et al.* 2007, Atkinson and Stillman 2008, Harrison 2008). Increased coastal development and recreation has also been implicated with nest failure and the decline of the Little Tern and other species in numerous locations throughout northern NSW, through the deliberate removal of eggs, crushing of eggs by vehicles, and intense disturbance resulting in birds deserting nests (Morris 1980, Holmes in Morris 1980). Once again, much research has been carried out in the northern hemisphere in regard to the impact of recreational disturbance on shorebirds/waders, while in Australia there have been very few detailed or quantitative studies (Lane 1987, Buick and Paton 1989, Taylor and Bester 1999, Paton 2000, Holmes *et al.* 2005, Weston and Elgar 2005, 2007).

### *1.8.2 Removal of food resources*

In past years, beach bivalves or “pipis”, the main food source of beach inhabiting Australian Pied Oystercatchers in northern NSW, were widely collected as a food source by coastal Aboriginal tribes. Now they are often taken for bait by surf-fishers around south-eastern Australia and Tasmania. Commercial collectors also harvest the pipi for human consumption, though in fewer localities than previous years (Saenger and Keyte 1990). Non-mechanical shell fisheries are authorized throughout Australia. However, in NSW only six hand-gathering licences (for *Donax deltoides*) have been issued and shall not increase in number (NSW DPI unpublished data). Nonetheless, this activity has the potential to negatively impact upon Australian Pied Oystercatchers, as the target shellfish species is also the primary prey species of oystercatchers in the northern region. Furthermore, the beaches targeted for collection accommodate high densities of Australian Pied Oystercatchers (Owner and Rohweder 2003). As breeding success has been low (Moffatt 2005) in areas where harvesting occurs and stocks appear to have been reduced in recent years, there is concern over the removal of this food supply (Owner 1998, Allen 2006). Although commercial harvesting of shell-fish has been demonstrated to have devastating impacts on oystercatcher and other wader populations internationally (Stillman *et al.* 2001, West *et al.* 2003, Atkinson *et al.* 2003, Ens 2006), this has not been investigated in Australia. Furthermore, although shell-fish are harvested, no detailed study has been undertaken to determine the sustainability of such practices. It is only recently that the basic biology of the pipi has been examined (Murray-Jones 1999) and most fisheries research still focuses on recreational and commercial catches and profits (Murray-Jones and Steffe 2000, Tanner and Liggins 2001). The fauna inhabiting Australian beaches and estuaries is largely understudied (Jones and Short 1995, Hacking 2007).

Bait digging also occurs throughout Australia, both commercially and recreationally, for beach worms, another food source of the Australian Pied Oystercatcher. Such activities can also result in a strong local reduction of prey (Lambeck *et al.* 1996). However, again, this has not been investigated in Australia. Although both species, pipis and worms, are removed by non-mechanical means, and thus have less potential to damage fauna as opposed to the previous mechanic removal, human presence during this process has been reported to also disturb feeding birds (Lambeck *et al.* 1996, West *et al.* 2002, Stillman 2007).

Traditional harvesting of large gastropods (*Turbo* spp.) for human consumption along with removal of ascidians (*Pyura* spp.) by fishers for bait (Chafer 1993) continues to occur within the state. Both species are consumed by the Sooty Oystercatcher (A. Harrison pers. obs.).

### *1.8.3 Predation*

Historically, the men of indigenous tribes in coastal regions were known to hunt a wide range of ground-nesting and other birds and also take their eggs and chicks as a source of food (Australian Government 2008). Native generalist predators such as the Thylacine (*Thylacinus cynocephalus*) and Eastern Quoll (*Dasyurus viverrinus*) were also present and preyed upon birds (Long *et al.* 2002, Johnson 2006). Hence, Australian species have coexisted with predators for a very long time. However, the introduction of the Dingo (*Canis lupus dingo*s), some 4-5,000 years ago (Corbett 1995, Savolainen *et al.* 2004), followed by the introduction of the Feral Dog (*C. l. familiaris*) and Red Fox (*Vulpes vulpes*) not long after the arrival of Europeans, meant that predation upon ground-nesting birds, their nests and chicks was likely exacerbated (DECC 2008). On mainland Australia, predation by the introduced Red Fox, particularly on ground-nesting species, has now long been recognised to have devastating impacts, with the ability to drive prey populations almost to extinction (Saunders *et al.* 1995, Short 2004)

Today, predation, largely by the generalist Red Fox, is thought to be one of the major contributors to shorebird mortality, reduced breeding success and the resultant decline of nesting shorebirds within Australia (Smith 1990, Smith 1991, Garnett 1992, Marchant and Higgins 1993, Priest *et al.* 2002). Nests are very accessible, as they are placed in open locations on the ground where incubating birds and their eggs and chicks are extremely vulnerable to predators. It is not only eggs and chicks that are subject to predation: juveniles and even adults of various shorebird species have been observed to be preyed upon (Weston *et al.* 2005). Predation by this species is also a major concern for the Hooded Plover at beach sites in Victoria (Weston 1999), and for the Australian Pied Oystercatcher in northern and southern NSW (Wellman *et al.* 2000, Jarman and Keating 2006). Some have also suggested that foxes and other predators will continue to destroy nests at traditional sites, as they retain knowledge of where these nests occur (Hötker and Segebade 2000).

Other species responsible for predation today include rats (*Rattus rattus*, *R. norvegicus*), domestic and feral dogs and cats (*Felis catus*). Dogs in particular have been identified in numerous studies to pose a threat to shorebirds in recent decades (Retallick and Bolitho 1993, Miller *et al.* 2001, Weston 2001, Priest *et al.* 2002, Baird and Dann 2003), with reports of a single animal destroying many nests, eggs and chicks in just one visit (Smith 1990). However, native predators also exist and include corvids, gulls, raptors and possibly even goannas (*Varanus varius*) (Lane 1987, Smith 1990, Smith 1991, Marchant and Higgins 1993, Priest *et al.* 2002). Gulls are reported nest predators, particularly of the Little Tern (Egan 1990, Smith 1991), while raptors such as the White-bellied Sea Eagle (*Haliaeetus leucogaster*), Whistling Kite (*Haliastur sphenurus*) and Swamp Harrier (*Circus approximans*) have been known to attack and prey upon adult Masked Lapwings (*Vanellus miles*) and Sooty Oystercatchers (Minton 1989, Marchant and Higgins 1993, Weston *et al.* 1995). Swamp Harriers, Kelp Gulls (*Larus dominicanus*), Silver Gulls (*L. novaehollandiae*), Forest Ravens (*Corvus tasmanicus*) and Tasmanian Native-hens (*Gallinula mortierii*) have also been observed to attack the Australian Pied Oystercatcher (Marchant and Higgins 1993).

Although disturbance by some predators, such as gulls, raptors and corvids, can have detrimental effects on breeding success through actual predation, continual disturbance by these species may also keep parents away from their eggs and chicks, resulting in energetic costs (Smith 1990). Furthermore, these species may compete for and steal food (kleptoparasitism) potentially reducing fitness of both migratory and resident species (Dann 1979, Hulsman 1984, Dann 1987, Egan 1990, Smith 1991, Harris and Wanless 1997). Owing to their close association with humans, as a result of additional food resources we provide, numbers of these predators have increased over past years and are likely to continue to rise, as will the impact upon resident species (Priest *et al.* 2002, Piper and Caterall 2006).

Although it is widely accepted that all of the above mentioned species are responsible for nest failure, again the effects have rarely been quantified (Priest *et al.* 2002).

### *1.8.4 Climatic conditions and coastal pollution*

Other threats include tidal flooding of nests, extreme heat, cold and storms, changes to hydrological systems, and pollution of coastal areas (Marchant and Higgins 1993, Lauro and Nol 1993, 1995a, Davis *et al.* 2001, Priest *et al.* 2002, Stillman *et al.* 2007), all of which may directly influence hatching success, and indirectly influence chick survival and growth, as well as foraging time and food availability.

Tidal flooding associated with spring tides and storm events are predicted to become more frequent and intense in coming years (Church *et al.* 2004, CSIRO 2008). Given that nests currently are generally placed at the water's edge, they are very susceptible to fluctuations in water levels. Predicted sea-level rise could have devastating effects on coastal nesting species such as oystercatchers via habitat loss, a decline in food availability and by pushing them closer to humans (Jones *et al.* 2004, Chambers *et al.* 2005, Wormworth and Mallon 2006). In Tasmania for example, where roads have been built alongside low-lying estuaries oystercatchers are being forced to roost on roads, and feed on roadside verges during extreme high tides, while they wait for mudflats to become exposed enough to feed, such behaviour has likely resulted in energetic costs but also, resulted in birds being killed by motorists (Harrison 2008).

Drought may also have a negative impact on shorebirds. Australia has suffered the longest drought in history, with lower than average rainfall recorded over the past decade in many regions, including NSW (Bond *et al.* 2008). Increased air and water temperature along with lack of water movement, resulting from severely dry climatic conditions, can result in fish kills and loss of macrofauna in freshwater systems (Boulton and Lake 1992, Boulton *et* *al.* 1992, Velasco and Millan 1998) and in enclosed coastal lagoons and estuaries (Lugg 2000). The lack of water flow may also have follow-on effects for near-shore ocean ecosystems. Ruello (1973), Bilkovic *et al.* (2006) and Peterson and Jennings (2007), have all previously indicated that high river flows are correlated with good productivity of marine species. Therefore lack of flow has potential to impact upon key food resources. Most research on ecosystem linkages thus far has focused on impacts of urbanisation and increased levels of nutrients, sedimentation, pesticides and heavy metals flowing into systems during periods of high rainfall (Ferguson *et al.* 2003, Eyre 2000, Bilkovic *et al.* 2006,) which obviously have negative impacts on fauna including macro-invertebrates and coral (Saenger and Keyte 1990, Humphrey *et al.* 2008). However, little information exists on the reverse trend associated with drought in the estuarine or near-shore environment.

## 1.9 Objectives and aims of thesis

Detailed scientific investigations of the ecology of the species and the impact of threats are imperative to the conservation of vulnerable species such as the Australian Pied and Sooty Oystercatcher, as this will provide the basis for effective management plans for the future. Although much detailed work has been undertaken internationally, and information on counts and movements has been generated for some regions of Australia, there remains a paucity of information on distribution, biology, ecology and impact of threats specific to the Australian Pied Oystercatcher and Sooty Oystercatcher in NSW. Until quantitative studies are undertaken, particularly on the impacts of disturbance, management may be ineffective (Lane 1987, Hecht and Nickerson 1999).

### *1.9.1 Objective*

The main objectives of this thesis were to examine the ecology and breeding biology of the Australian Pied Oystercatcher (*Haematopus longirostris*) and Sooty Oystercatcher (*H. fuliginosus*) in sub-tropical NSW, to identify key threatening processes within the region and to assess the impact of those threats upon each species to provide guidance for future management.

### *1.9.2 Aims of specific chapters*

Specific aims of chapter two were to:

- determine the size of the current population of Sooty Oystercatchers in sub-tropical northern NSW;

- examine population trends using past and present estimates;
- determine the number of breeding pairs and sites used for nesting;
- determine reproductive success;
- identify key features including large-scale landscape features and small-scale fauna of specific headlands, of habitat used by breeding and non-breeding birds; and
- identify potential additional breeding habitat on the basis of modelling.

Specific aims of chapter three were to:

- provide an estimate of Australian Pied Oystercatcher population size and examine population trends using current and past count data;
- determine the current distribution, including breeding sites;
- identify factors associated with the presence of oystercatchers; and
- determine whether additional nesting habitat was available to provide potential for growth.

Specific aims of chapter four were to:

- describe breeding biology of Australian Pied Oystercatcher;
- estimate reproductive success (hatching, fledging and productivity rate);
- identify the causes of egg and chick failure;
- assess small-scale nesting habitat and food availability; and
- compare the breeding success (hatching and fledging success) and productivity between birds occupying beach and estuarine habitat.

Specific aims of chapter five were to:

- determine whether disturbance constitutes a management issue for the Australian Pied Oystercatcher through monitoring disturbance at nesting sites;
- monitor the behavioural responses of incubating Australian Pied Oystercatchers;
- determine which recreational activities (or stimuli) impact most upon the behaviour of the Australian Pied Oystercatcher during incubation; and
- suggest set-back or buffer distances at which disturbance would be minimised.

Specific aims of chapter six, the final concluding chapter, were to:

- synthesise important results from each of the previous chapters;
- assess the population sustainability of Australian Pied Oystercatchers and ;

- provide recommendations for management actions and future research for both the Australian Pied Oystercatchers and Sooty Oystercatcher in northern NSW.

Following the commencement of this project, a Threatened Species (Australian Pied Oystercatcher) Management Strategy (TSMS) was proposed and was then developed for the Australian Pied Oystercatcher in northern NSW simultaneously to the work undertaken in this thesis. Many of the recommended actions from this thesis and additional reports were subsequently included as actions in that document.

### *1.9.3 Content of appendices*

Appendix A is a publication providing documentation of an unusual breeding association of the usually monogamous Australian Pied Oystercatchers. A long-term cooperative breeding trio was monitored and the behaviour of individuals involved is discussed. Such a well documented association had not previously been published for the species.

Appendix B contains a supplementary report submitted to the NSW Department of Lands, in an effort to aid management decisions for the then pending TSMS. The report focuses on recreational disturbance and the direct effects that it has on shorebirds at South Ballina Beach, and documents the traffic and other issues at the site and their impacts. It also reports on the effectiveness of some management actions trialled during 2005 at the location.

Appendix C contains a list detailing efforts made to educate and raise public awareness about threatened shorebirds and the issues they face, and to encourage community involvement. Numerous school visits, workshops, education days were held, and brochures and articles were written in support of the TSMS

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Lastly, I would also like to advise the reader that this thesis has been written in paper style rather than traditional thesis style. Consequently, there is some repetition in the methodology and study area between chapters. Also, the formatting in Chapter 4 is slightly different to the rest of the thesis as it has been submitted for publication and is currently in final review.

**CHAPTER 2**

Abundance, habitat use and aspects of breeding biology of the Sooty Oystercatcher (*Haematopus f. fuliginosis*) in sub-tropical northern New South Wales

**Abstract**

The Sooty Oystercatcher (*H. f. fuliginosis*), while not nationally threatened, is listed as a vulnerable species in New South Wales, where the population is critically low, yet basic information is lacking. Accordingly, population estimates, distribution and habitat use were determined during 2003 to 2005 for breeding and non-breeding individuals along a 186 km section of the northern New South Wales coastline. Breeding biology was also examined during 2003 and 2004. Based on maximum autumn counts, known breeding pairs and movements between sites, the population was estimated to contain 45-59 individuals, of which six pairs bred. This count, compared to past estimates, indicates that despite annual fluctuations, numbers have remained fairly stable over the past decade. Breeding success was high, with 1.00 and 0.83 chicks fledged per pair in 2003 and 2004 respectively. Occurrence of Sooty Oystercatchers was associated with the presence of islands and number of rocky headlands. Use of the coastline varied between three main regions, The Richmond River to just north of Woody Head was not used, Woody Head to Wooli was used primarily by floaters, and the remaining coastline including the Solitary Islands, was used primarily for breeding. Presence of soil and low vegetation, along with lack of Silver Gulls (*Larus novaehollandiae*) were the best predictors of nesting Sooty Oystercatchers, distance of island off-shore from the mainland was not a determining factor. Additional unoccupied and suitable nesting habitat was identified. However, the population remains small and is likely to be below capacity. Available data suggest that although the population is stable, the species remains at risk. Coordinated long-term counts and leg-flagging are required to determine population trends and individual movements at the state and national scale. Obtaining details such as age at first breeding, survival to breeding and adult survivorship should be the priority for future research and publication.

**Key words**: Australian Oystercatchers, distribution, breeding sites, Solitary Islands, carrying capacity, habitat use, status, threatened species.

## 2.1 Introduction

Seabirds and shorebirds are threatened globally by habitat loss, predation and human disturbance (Sutherland and Anderson 1993, Norris *et al.* 1998, Craik and Campbell 2000, Stillman *et al.* 2002, 2003, Goss-Custard *et al.* 2006). The Sooty Oystercatcher (*H. fuliginosis*), is one such species, with a national population, including both sub-species (southern: *H. f. fulignosus* and northern: *H. f. ophthalmicus*), of only 4000 individuals (Watkins 1993, Geering *et al.* 2007). Individuals, pairs and small groups of the sub-species are sparsely distributed around the Australian coastline occupying southern and northern ranges respectively, with high numbers in only a few key locations, such as the Furneaux Islands of Tasmania (560 individuals), Corner and Shallow Inlets (270), Nuytsland Nature Reserve in Western Australia (180), and Murat Bay in South Australia (160) (Drummond 1984, Watkins 1993). However, numbers in New South Wales (NSW) are critically low, with an estimated population of only 200-245 individuals (Smith 1991, Watkins 1993). Although not listed as threatened nationally, *H. f. fulignosus* is listed as *Vulnerable* in NSW (Schedule 2 of the NSW *Threatened Species Conservation Act*, 1995). The sub-species was listed in NSW because the 'population has been reduced to a critical level', it has a 'limited distribution', is an 'ecological specialist' and has a 'poor recovery potential' (NPWS 2003).

Sooty Oystercatchers are coastal marine species that occur around temperate and tropical shorelines of Australia. They forage and roost on rocky shores of headlands, reefs, platforms and less frequently on sandy shores including beaches and estuaries (Lane 1987, Marchant and Higgins 1993, Lauro and Nol 1995a). Prey species include a range of limpets, chitons, large gastropods and ascidians, although availability is limited by daily tidal cycles (Marchant and Higgins 1993). Breeding occurs on off-shore and near-shore islands during September to January in NSW. Nests are simple scrapes just above the high water mark in which two to three camouflaged eggs are laid. Nest scrapes are often upon or among rock, shingle, pebble or sand and may be surrounded by or close to vegetation (Lane 1987, Lauro and Nol 1995a, Marchant and Higgins 1993). Pairs exhibit a high level of site fidelity during breeding and use traditional sites for nesting. During the non-breeding period flocks of up to 13 individuals are formed and birds become more mobile (Weston *et al.* 1995). Although not migratory, movements of up to 500 km have been recorded (Keating and Jarman 2003, Hansen *et al.* in prep).

Threats to the species are thought to include: human disturbance to feeding, roosting and nesting sites; destruction of nests, eggs and chicks by trampling or crushing by humans and dogs; disturbance and predation by feral and domestic animals and raptors; pollution of coastal areas; and storm damage (Lane 1987, Smith 1991, Newman 1991, Lauro and Nol 1993, Watkins 1993, Priest *et al.* 2002). However, typically the species nests at sites where human disturbance and mammalian predation is minimal (Garnett and Crowley 2000).

Although the population of Sooty Oystercatchers has been deemed at a critical level in NSW, it is one of the least studied oystercatchers of the world. Almost 15 years have passed since Weston *et al.* (1995) urged further research on the Sooty Oystercatcher and still little has been done. This paucity of solid information on population structure and dynamics, ecology and biology, means there is little basis upon which management decisions can be made. What little research has been done has generally focused on counts and movements, in the south of the country (Victoria and Tasmania) where the population is thought to be secure. Other basic information on breeding biology and foraging ecology has also rarely been documented for the species in Australia (but see Chafer 1992, 1994, Lauro and Nol 1995a 1995b, Weston *et al.* 1995).

Specific aims of this research were to: a) determine the current population of Sooty Oystercatchers in sub-tropical northern NSW, and examine population trends using past and present estimates; b) determine the number of breeding pairs and sites used for nesting; c) determine reproductive success; d) determine key habitat features for nesting and foraging; and e) identify potential additional breeding habitat. Management and future research are also discussed.

## 2.2 Study area

Surveys were undertaken between the southern wall of the Richmond River mouth (South Ballina Beach, 28°50’S, 153°31’E) and Bonville Estuary (Sawtell, 30°16’S, 153°05’E) in northern NSW, Australia (Figure 2.1). This 186 km stretch of coastline comprises both short, (i.e. less than several kilometres) and long stretches of sandy beaches. Beaches range from wide gently sloping beaches with fine sediment, through to narrow beaches with small high energy waves and coarser sediment. Interspersed are rocky headlands varying in aspect and exposure with intertidal rock platforms ranging from simple flat rock or boulder fields accommodating little fauna to complex rock formations with a large biomass of invertebrate fauna. Also interspersed are 13 tidal estuaries varying in catchment area (ranging < 20 $km^2$ to 22,400 $km^2$), length (ranging < 5 km to 250 km), flora composition, waterflow and sediment movements.

The coastline can broadly be grouped into three regions differing in large-scale landscape features. The first region, from the Richmond River to the Woody Head just north of the Clarence River, comprises long stretches of sandy beaches, no islands and few rocky shores (two headlands and a break wall entrance). The second region, Woody Head to Wooli, also lacks offshore islands, but has one island connected via sand/rock and four near-shore reefs, approximately 22 rocky headlands and platforms, some with tidal pools, two sets of break walls and 24 short sand/gravel beaches. The third, Wooli to Sawtell, consists of seven offshore islands and large offshore rocks, seven small near-shore islands and reefs, 29 headlands, two sets of break walls, an estuary wall, a large harbour (Coffs Harbour) bordered by rock and numerous short sand/gravel beaches. Much of this latter (third) region is protected, being within the bounds of the Solitary Islands Marine Park (Figure 2.1).

Surveys were undertaken along all of the coastlines mentioned above and also on all of the major islands, rocks and reefs within the Solitary Island Marine Park (Plover, South, South West, Split, North, North West, Muttonbird, Little Muttonbird and Korffs Islands, North-West Rock, Flat Top Point, Woolgoolga Reef and Shingle Break) and surrounds (Sawtell Island). These range from small (< 2 ha) low rocky outcrops with no soil or vegetation to large rocky islands (max. 10 ha) with a low ground cover of vegetation. Five of the large islands are protected under the Marine Park Act (1997) and have restricted access. Although, Muttonbird Island and smaller rocky islands, connected to the mainland via sand-spits, such as Sawtell Island and Flat Top Point, are also protected under the Marine Park Act, these islands are easily accessed and regularly used for recreation at low tide. While South Solitary Island also has protection, historically the site was disturbed, with the erection of a lighthouse that was manned between 1880 and 1975 (Lighthouses of Australia Inc. 2003).

The coastline is subject to mean tidal range of 1.2-2 m. Average air temperatures range between 12°C during the winter and 21-24°C during the summer. Rainfall is variable with an annual average of 1200-1600 mm (BOM 2005). However, severe drought was experienced during 2003 and 2004.

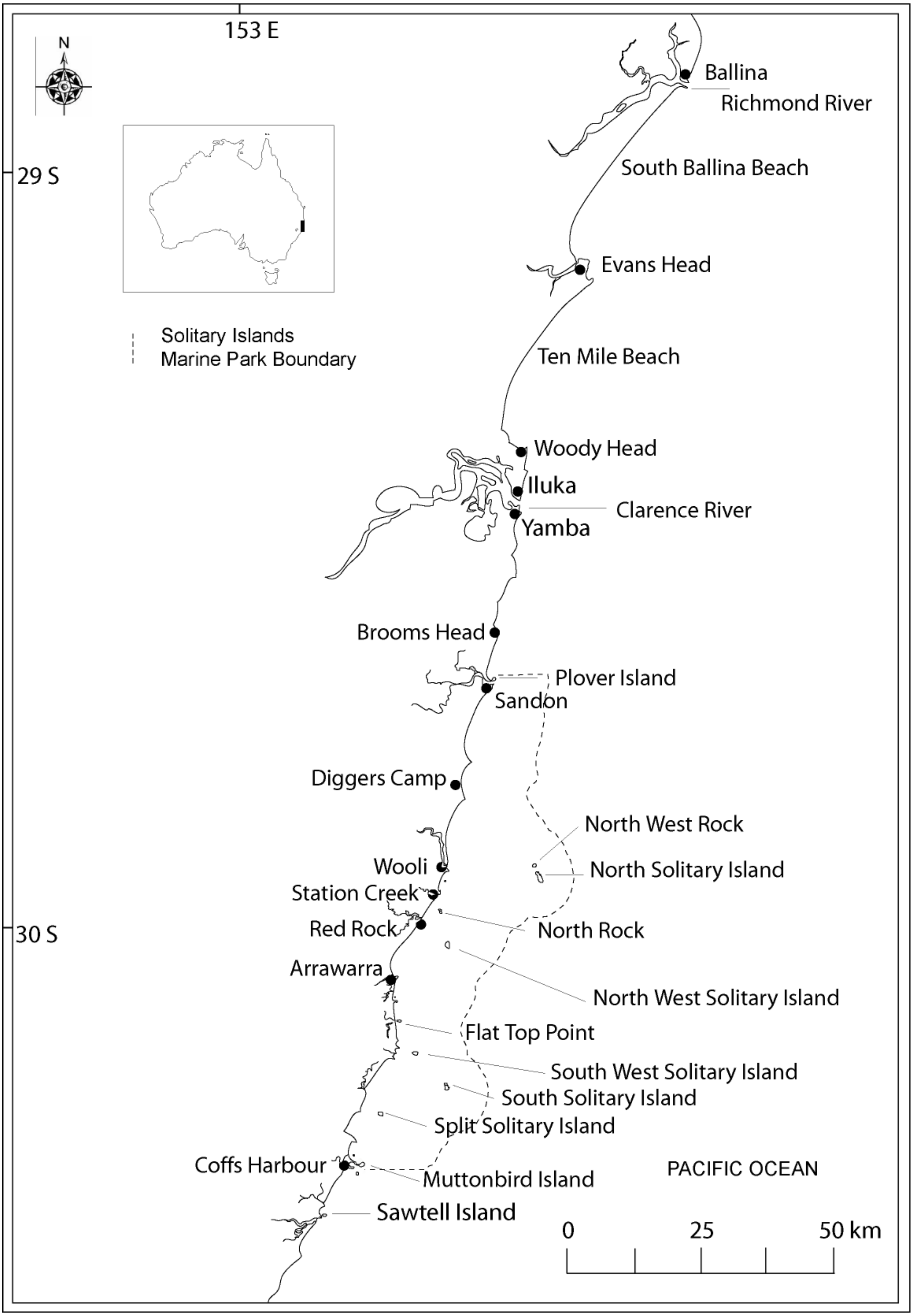


**Figure 2.1**: Map of survey region within northern NSW.

## 2.3 Methods

### *2.3.1 Broad-scale distribution and abundance*

Surveys were undertaken seasonally throughout 2003, 2004 and 2005 to estimate the population of Sooty Oystercatchers. Beaches, headlands, offshore and near-shore islands and the lower reaches of estuaries within the region were included. Surveys were conducted on foot or in the case of islands, by boat. Searches were done during low tide and an effort was made to survey the entire region in minimal time to minimise disturbance to birds and avoid double-counting. Location, number of birds, behaviour and sex (based on bill length) was recorded. Owing to limited road access between sections of coastline, counts at Minnie Water, Wooli and Station Creek/Pebbly Beach (Figure 2.1) were generally separated by one day, thus double-counting may have occurred in these regions. These possible over-estimations were minimised by additional surveys in those regions as indicated below. During austral spring and summer when breeding occurred, numbers of breeders, non-breeding residents and floaters were determined. Observations were made with the use of 8x10 (Ziess) binoculars and a 40x magnification (Kowa) viewing scope.

### *2.3.2 Behaviour and movements*

Locations were visited several times throughout each season during 2003 and 2004, often during the same or consecutive days and throughout the low tide period. Time was spent searching for birds at sites where they had been previously recorded and foraging behaviour was quantified. If birds were not present at a particular site, the near-by headlands, reef platforms and estuaries were also searched. Once found, birds were methodically observed (focal-animal surveys) for an hour at a time. However, some were then observed for up to seven additional hours (generally totalling two to three) in the day. On departure of birds, the direction of flight and destination were recorded where possible (flight to islands was very obvious). If destinations were not obvious, other nearby locations were searched and where movement between certain locations was suspected, concurrent monitoring (including volunteers) of these locations was undertaken. This monitoring (totalling approximately 85 hrs) provided insight into movement patterns, habitat use and aided in providing a more accurate population estimate by further determining where over-estimates may have occurred during counts. Observations by local bird watchers and general public were also sought in an effort to increase the number of locations where Sooty Oystercatchers were known to occur.

### *2.3.3 Breeding biology*

Pairs were monitored from September to March during 2003 and 2004. Near-shore islands connected via sand spits were visited weekly, while offshore islands were visited once each in October and November 2003, the latter coinciding with the peak egg-laying period (Keating and Jarman 2003). Offshore islands were not visited more frequently due to poor weather, cost and time limitations. All breeding locations and nest sites were precisely noted along with nest contents. Additional visits were attempted to determine hatching and fledging success. However, these were often not possible, thus few chicks were observed. Consequently, six articles were published in newspapers and distributed throughout the study region in February 2004 and March 2005, calling for sightings of juveniles to be reported. All reported sightings were then investigated to better determine the number of fledglings added to the population.

### *2.3.4 Habitat assessment*

The diversity and abundance of intertidal rocky shore fauna were sampled seasonally at eight locations during 2003, using a stratified random method. Five quadrats (1 m x 1 m) were randomly placed at each of three sites at each location, randomly chosen within the intertidal zone, ten metres apart during the low tide period. This was undertaken at six randomly chosen locations that frequently accommodated feeding birds and two that did not. This unbalanced design was unavoidable as most headlands were used by Sooty Oystercatchers. Prey species were identified, counted and recorded on site.

Features of all islands, islets and reefs (14 in total) were also determined including distance off-shore, area, elevation above mean sea level, whether soil and vegetation were present, breeding history of other bird species and habitat zoning category (defined and assigned by the Marine Park Authority (MPA), as either no protection, habitat protection zone, or sanctuary zone) and tabulated. During the 2004 visits to islands, counts were also made of other avian species present.

### *2.3.5 Statistical analysis*

An information-theoretic modelling approach, using R (Core Development Team 2006), was applied, whereby models with factors or groups of factors are constructed, which could explain Sooty Oystercatcher presence across sites (Johnson and Omland 2004). Generalised logistic regression analysis was applied for both foraging and nesting habitat. Macrofauna were included for foraging habitat and island characteristics were included for nesting habitat. Various habitat models, with several competing hypotheses were then tested, lending support to a particular hypothesis depending on which model was identified as best.

For each model tested an Akaike's Information Criterion (AIC) value was calculated. The calculated AIC value is an estimator of the expected distance between the conceptual truth and model approximated truth that provides a maximised log-likelihood value. This value is indicative of the likelihood that the model best explains the conceptual truth, whereby the lower the value the greater the likelihood of the best model (Burnham and Anderson 2002). Following this procedure, a modified AIC value, the $AIC_c$ value, was calculated. These modified $AIC_c$ values were used rather than the maximised log-likelihood AIC values as the number of parameters (K) was relatively large compared to the sample size (n), i.e. when $n/K < 40$ (Burnham and Anderson 2002). The $AIC_c$ values were calculated as follows:

$$AIC = -2\log(L) + 2K, \text{ therefore,}$$
$$AIC_c = -2\log(L) + 2K + 2K(K+1)/(n-K-1)$$

where $\log(L)$ = log likelihood of model
K = total number of parameters in the model
n = sample size

A rescaling on the $AIC_c$ values was then undertaken to allow for a comparison and ranking of candidate models. The best model as suggested by the lowest AIC was given the value 0. The difference between all models was then calculated:

$$\Delta_i = AIC_{c(i)} - \min AIC_{c(i)}$$

Using such rescaling, models for which $\Delta_i$ values within 2 in relation to the best model have substantial support. Values of 3-7 from the best model have considerably less support, while models having $\Delta_i > 10$ have minimal support (Burnham and Anderson 2002). Further to this, normalized Akaike weights ($w_i$) were calculated. Such weightings provide strength of evidence for alternative models, i.e. the greater the value the greater "weight of evidence" for a particular model. Akaike weights ($w_i$) were calculated as follows:

$$w_i = \exp(-\Delta_i / 2) / \sum \exp(-\Delta_i / 2)$$

These normalized weights conveniently sum to one. Therefore, the best model, the one showing the strongest support, will have the greatest weight.

## 2.4 Results

### *2.4.1 Abundance*

Sooty Oystercatchers were particularly hard to assess due to the number of floaters within the population and their frequent movements. Nonetheless, a minimum of 26 resident adults (12 pairs and two singles) consistently occupied particular locations within the region. In addition to this a maximum count of 29 floaters (birds that were not breeding or territorial, and moved around locally, tending to occur in small groups in a range of regular locations) was recorded during 2003, to provide a maximum estimate of 55 individuals (Table 2.1). Of resident birds, only six pairs (44%) attempted to breed during 2003 and strongly defended nesting territories, aggressively attacking intruders upon approach.

During 2004, less thorough counts yielded 106 birds, again including the 26 resident adults of which 12 (six pairs) attempted to breed. During 2005, the number of residents (and breeders) remained stable but the maximum count was 94 individuals. Hence, although resident pairs remained consistent, the number of floaters fluctuated widely between years (Table 2.1). Fluctuations may have been owing to double-counting, as birds were very active along some sections of coast.

Maximum counts of Sooty Oystercatchers averaged over 2003-2005 provide a population estimate of 85 individuals. However, adjusting for double counting, on the basis of maximum autumn counts and hours of monitoring of behaviour to determine subgroups of birds moving between particular areas (described in section 2.4.3), the total population is more accurately estimated to contain between 45 and 59 individuals (Table 2.1). The density (based on the maximum adjusted estimate) of Sooty Oystercatchers along the entire surveyed distance of the north coast was 0.32 birds $km^{-1}$. However, birds were not spread evenly along the coast and occupied offshore islands.

### *2.4.2 Distribution*

Three distinct sections of use were identified within the surveyed region: 1) Richmond River south to just north of Woody Head (approximately 65 km of coastline), which was generally not used, 2) Woody Head south to Wooli (approximately 65 km of coastline), which was primarily used by large groups of floaters (including immature birds) for feeding and roosting, and 3) Wooli south to Sawtell, including the Solitary Islands (approximately 55 km), which was used by breeding pairs and non-breeding residents. Within the latter two sections (included in Figure 2.2), the coast was further partitioned by groups of oystercatchers so that 13 areas were primarily used (Table 2.1). However, movement between these was evident.

**Table 2.1**: Population estimates for Sooty Oystercatchers in northern NSW, including comparison of the number of resident adults and total numbers during 2003, 2004 and 2005. Estimated area totals are based on numbers of residents within each area (divided in table), plus estimated number of floaters considering movements among locations.

| Area groups | Locations | Resident adults | Total (max. count) 2003 | 2004 | 2005 | Estimated Area Totals |
|---|---|---|---|---|---|---|
| 1 | Ten Mile Beach | 0 | 1 | 0 | 0 | 0 |
| 2 | Woody Head | 0 | 9 | 11 | 7 | 9-11 |
| | Clarence River | 0 | 0 | 6 | 20 | |
| 3 | Brooms Head | 0 | 2 | 2 | 2 | |
| | Plover Island** | 2 | 0 | 0 | 0 | 2-4 |
| | Sandon Estuary | 0 | 2 | 2 | 2 | |
| 4 | Minnie Water | 0 | 2 | 4 | 5 | |
| | Diggers Camp | 0 | 7 | 19 | 9 | |
| | Wooli | 0 | 7 | 9 | 9 | 9-19 |
| | North West Rock | 0 | 0 | 1 | 0 | |
| | North Solitary Island* | 2 | 1 | 3 | 5 | |
| | Station Creek | 2 | 5 | 4 | 7 | |
| 5 | North Rock | 0 | 3 | 3 | 1 | |
| | Red Rock | 0 | 2 | 2 | 2 | 4 |
| | North West Solit. Isl.* | 2 | 0 | 4 | 3 | |
| 6 | Corindi Beach | 0 | 2 | 1 | 2 | |
| | Arrawarra | 2 | 2 | 5 | 5 | 5 |
| | Mullawarra | 1 | 2 | 3 | 2 | |
| 7 | Flat Top Rock* | 2 | 0 | 1 | 0 | |
| | Sandy Beach | 0 | 2 | 2 | 4 | 4-6 |
| 8 | South West Solit. Isl.* | 2 | 0 | 0 | 0 | |
| | Emerald Beach | 2 | 0 | 8 | 0 | |
| | South Solitary Island | 0 | 0 | 1 | 1 | 0 |
| 10 | Moonee | 2 | 0 | 0 | 0 | 2 |
| | Split Solitary Island | 0 | 2 | 2 | 1 | |
| 11 | Sapphire/Korora | 2 | 1 | 5 | 5 | 5 |
| 12 | Little Muttonbird Isl. | 0 | 0 | 2 | 0 | |
| | Coffs Creek | 0 | 2 | 3 | 2 | 3 |
| | Muttonbird Island* | 2 | 0 | 0 | 0 | |
| | Gallows Beach | 1 | 0 | 0 | 0 | |
| 13 | Boambee Beach/Bay | 0 | 1 | 0 | 0 | |
| | Sawtell Island* | 2 | 0 | 0 | 0 | 2 |
| | Totals | 26 | 55 | 106 | 94 | 45-59 |
| | Average Count | | | 85 | | 52 |

Note: locations where Sooty Oystercatchers were consistently absent have not been included in table. Numbers of resident adults were consistent during 2003-2005. ** indicates possible nesting site, * indicates breeding site. Area groups are indicated on the basis of known movements between neighbouring locations.

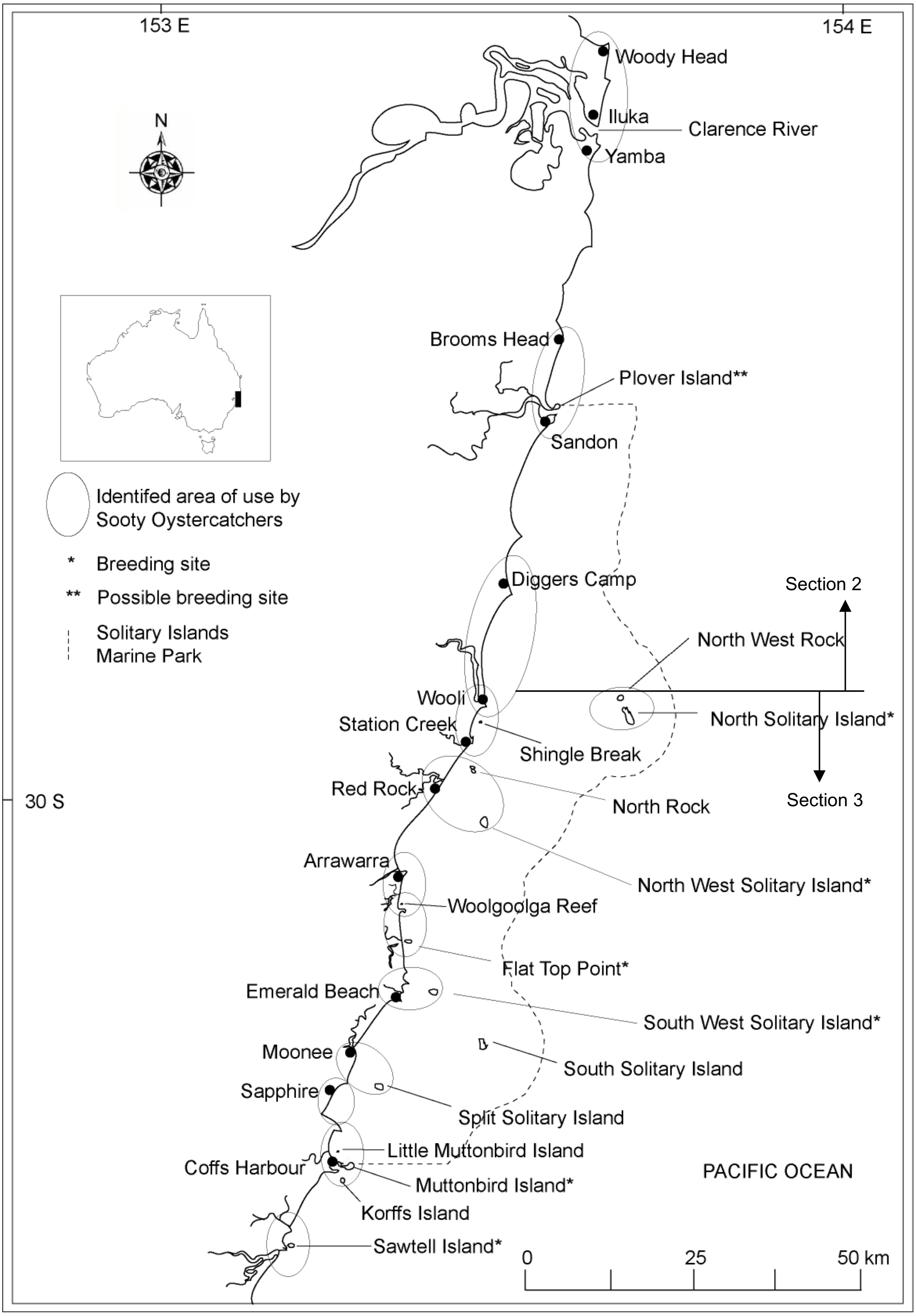


**Figure 2.2**: Map of the two major sections of coast used by breeding and foraging Sooty Oystercatchers in northern NSW, and the 13 areas primarily used within these.

All breeding pairs nested on islands that have historically supported the species. All but one pair nested on islands within the Solitary Island Marine Park. Offshore breeding sites used by Sooty Oystercatchers included North Solitary Island, North-west Solitary Island and South-west Solitary Island. Other islands included Flat Top Point, Muttonbird Island and Sawtell Island, all of which can be accessed by walking or wading from the mainland and were included within the third area of use. Nesting was also suspected on Plover Island, within section two, but not confirmed (Figure 2.2). This was however only suspected on the basis that this was a near-shore island and that one pair occupied the site throughout the breeding season. All breeding pairs were faithful to nesting territories and surrounding area, generally excluding other Sooty Oystercatchers throughout the year (within about 2 km). Only one pair of breeding birds was present per nesting island. Average nesting density was low, at 0.28 pairs $ha^{-1}$ on nesting islands (ranging from 0.11 – 0.53 pairs $ha^{-1}$).

*2.4.3 Group size and habitat use*

Flocks of up to 20 Sooty Oystercatchers were observed in each of two areas used by non-breeding birds along the mainland coast, the Woody Head/Clarence River area and the Diggers Camp area (Figure 2.2) during the March/April counts when new recruits were present. However, during most counts in both these areas between 7 - 11 individuals were seen either foraging on exposed rocky platforms or roosting. It is likely that interchange between the Woody Head and Diggers Camp groups occurred to produce the larger numbers observed. Birds at Diggers Camp were observed to constantly fly in and out, over the hours of low tide, to the north and south. Hence, it is also possible that birds usually seen in the Wooli area to the south (7 - 9 birds) also flock with the Diggers Camp birds. The merging of these groups in addition to a few new recruits would provide the large numbers observed there. Birds used both Diggers Camp and Wooli for foraging and roosting and were observed to move between these areas during coordinated observations. Both these areas are adjacent to North Solitary Island and movement between mainland and the island was also noted (Figure 2.2). While at Wooli, birds foraged in sheltered rocky/rubble areas and on rocks along the entrance to the Wooli River/estuary.

The Red Rock/North West Solitary Island group included one breeding pair that remained on the island during breeding and made trips between the island and mainland during other periods. Fledglings from these birds were sighted on the mainland roosting on beaches, foraging on rocky headlands and on rocks along the entrance of the tidal estuary

(Figure 2.2) with resident adults. A small number of additional floaters were also sighted foraging and roosting in this area (Table 2.1).

Small groups were also seen at headlands in the Arrawarra to Sawtell Island area, with movement between headlands and islands. During non-breeding periods, pairs foraged on mainland headlands, rocky shores and rubble areas within estuaries before departing for the islands following the turn of the tide and sometimes at dusk. However, all pairs were observed to use mainland beaches and rocky headlands as daytime roosts. Arrawarra generally contained three residents, a pair and a single female that was driven to the south when birds encountered one another. However, a maximum of five birds was also observed foraging and roosting there (Table 2.1), possibly including birds from Flat Top Point following breeding (movement between Arrawarra and Flat Top was sighted). South Solitary Island was not used for nesting and only one Sooty Oystercatcher was sighted there during both 2004 and 2005, along with one Australian Pied Oystercatcher. The Muttonbird Island pair foraged during the non-breeding season on the island, within Coffs Creek estuary on rocks/rubble encrusted with oysters, on the rocky shore of Little Muttonbird Island and at the Jetty Beach on the ascidian-encrusted pilings (Figure 2.2). The lone bird (female) occurring within relatively close proximity to these birds (< 2 km) generally occurred on rocky headlands and platforms to the immediate south and did not interact with the pair.

Birds were not found on rock platforms that consisted of flat smooth rocks with few invertebrates present, smooth boulders fields, or cliffs but they generally occurred on wide and complex rock formations. Sooty Oystercatchers did not forage on sandflats in northern NSW. Peak foraging occurred within the two hours prior to low tide and extended until one hour following the low tide. Breeding pairs generally did not join flocks and remained within a few kilometers of nesting territories throughout the year (Figure 2.2).

### *2.4.4 Breeding biology*

Four of the six breeding pairs were monitored in 2003. The remaining two pairs displayed breeding behaviour such as testing nest scrapes, but were only confirmed as breeders by the presence of juveniles, after reports from community members in response to newspaper articles. Breeding pairs exhibited a strong pair-bond, with pairs observed to copulate on the mainland during non-breeding periods (late May). Only one clutch was monitored per pair, laid during October and November. The four clutches observed all contained two eggs, all of which hatched. Four chicks fledged from these nests, plus two from unmonitored nests. Two nests were completely unsuccessful, while two nests fledged two chicks each, thus, of monitored nests, fledgling success was on average 50%. Mean net productivity was 1.0 chick per pair.

The two fledglings observed later in the season were single birds (with parents) indicating that either only one egg was laid or hatched or that one chick had been lost. The cause of chick loss was not determined, thus remains unknown. In 2004, five fledglings were observed within the region. However, accurate details on hatching success were not obtained. At a maximum, estimated productivity may have been 0.83 fledglings per pair for the six pairs during 2004. However, with such a small sample size and infrequent visits to islands, these estimates should be taken cautiously.

Chicks were fed exclusively on chitons and limpets close to the nest site. A large littering of shells was evident where young chicks had been fed, discarded shells were not removed by parents.

### *2.4.5 Habitat assessment*

Rocky shore fauna comprised many species of gastropod mollusc, chiton mollusc, bivalve mollusc (oysters and barnacles), ascidian, cnidarian and crustacean (Table 2.2). A number of floral species were also identified occurring on rocky shores (Table 2.2). Analysis of habitat indicated that several models had substantial support as the best predictors of Sooty Oystercatcher presence (Table 2.3). Models with substantial support contained limpets, oysters, Nerites, Neptune's Necklace (all of which were positively related to presence) and *Littorina* (negative influence). However, oysters, nerites and Neptune's necklace alone had the greatest weight of evidence for predicting presence (0.73-1.00).

Of the 14 islands and reefs assessed, 12 were within the Solitary Islands Marine Park and were protected as sanctuary (restricted fishing and collection) or habitat protection areas (restrictions to some commercial fishing) (Marine Park Regulations 1999). Five of the six sites identified as nesting habitat were within those zones. Only islands greater than 2 ha (ranging 2 - 9 ha) in size, that had soil with low vegetative cover and were higher than 5 m above sea level were used for nesting. Nesting islands ranged in distance from the mainland shore, from those connected to the mainland (0.1 km) via sand or rock to those 12 km offshore. Five of the six islands used for nesting had historically been devoid of breeding Silver Gulls (*Larus novaehollandiae*) (Table 2.4). The sixth island is also now devoid of breeding Silver Gulls.

**Table 2.2**: Flora and fauna recorded on rocky shores of northern NSW. Primary species consumed by Sooty Oystercatchers during focal animal surveys at different locations are also indicated. Location codes: 1 = Woody Head, 2 = Diggers Camp, 3 = Wooli, 4 = Red Rock, 5 = Arrawarra, 6 = Emerald Beach, 7 = Moonee, 8 = Muttonbird Island, 9 = Sawtell Island, 10 = Bonville and Boambee Estuaries.

| Phylum | Common Name | Species | Locations |
|---|---|---|---|
| Mollusca | Limpet | *Cellana tramoserica* | 1-9 |
| | Limpet | *Siphonaria denticulate* | 1-9 |
| | Chiton | *Onithochiton quercinus* | 2, 5, 6, 7, 8, 9 |
| | Chiton | *Liolophura* spp. | 2, 5, 6, 7, 8, 9 |
| | Winkle | *Bembicium nanum* | - |
| | Winkle | *Littorina unifasciata* | - |
| | Nerite | *Nerita atrementosa* | - |
| | Nerite | *Nerita albercillia* | 2, 4 |
| | Rock shell | *Morula marginalba* | - |
| | Rock shell | *Thasis orbita* | 1, 5, 6, 7, 8 |
| | Turban shell | *Turbo undulate* | 1, 5, 6, 7, 8 |
| | Top shell | *Austrocochlea constricta* | - |
| | Oyster | *Saccostrea glomerate* | 3, 4, 7, 10 |
| | Barnacle | *Catomerus polymerus* | 1, 2 |
| | Barnacle | *Tesseropora rosea* | 1, 2 |
| Crustaceans | Shore shrimp | *Palaemon litoreus* | - |
| | Crabs | Unidentified crab spp. | 5, 7 |
| Cnidaria | Anemone | *Oulactis mucosa* | - |
| Chordata | Sea squirt | *Pyura stolonifera* | 5, 7 |
| Chlorophyta | Sea lettuce | *Ulva australis* | - |
| | Green seaweed | *Entromorpha compressa* | - |
| Phaeophyta | Neptune’s necklace | *Hormosira banksii* | - |
| | Brown seaweed | *Sargassum sp.* | - |
| | Common kelp | *Ekolonia radiata* | - |
| | Brown fan algae | *Padina sp.* | - |

**Table 2.3**: Summary of generalised linear modelling using rocky shore macrofauna and flora as predictors for Sooty Oystercatcher presence.

| *Modelled Predictor Variables* | *AIC* | *AICc* | *$\Delta AIC_c$* | *Akaike weight* |
|---|---|---|---|---|
| Oysters, neptune's, nerites | 28.444 | 29.645 | 0.000 | 0.327 |
| Oysters, littorina, nerites, neptune's | 28.869 | 30.974 | 1.329 | 0.168 |
| Oysters, littorina, nerites | 30.129 | 31.329 | 1.684 | 0.141 |
| Limpets, oysters, nerites, neptune's | 29.254 | 31.359 | 1.714 | 0.139 |
| Littorina, neptune's, nerites | 30.321 | 31.521 | 1.876 | 0.128 |
| Limpets, littorina, oysters, nerites, neptune's | 29.720 | 33.05 | 3.405 | 0.060 |
| Limpets, bembecium, nerites, littorina, oysters, barnacles, neptune's | 27.38 | 34.38 | 4.735 | 0.031 |
| Limpets, bembecium, nerites, large gastropods, littorina, oysters, barnacles, neptune's | 28.4 | 38.000 | 8.355 | 0.005 |
| Limpets, bembecium, nerites, large gastropods, littorina, oysters, barnacles, neptune's, chitons | 29.7 | 42.557 | 12.912 | 0.001 |
| Limpets, bembecium, nerites, large gastropods, littorina, oysters, barnacles, neptune's, chitons, anemone | 31.53 | 48.45 | 18.805 | 0.000 |
| Limpets, bembecium, nerites, large gastropods, littorina, oysters, barnacles, neptune's, chitons, anemone, morula | 33.49 | 55.49 | 25.845 | 0.000 |
| Limpets, bembecium, nerites, large gastropods, littorina, oysters, barnacles, neptune's, chitons, anemone, morula, austrococlea | 35.45 | 63.814 | 34.169 | 0.000 |
| Limpets, bembecium, nerites, large gastropods, littorina, oysters, barnacles, neptune's, chitons, anemone, morula, austrococlea, pyura | 37.43 | 73.83 | 44.185 | 0.000 |

Note: The response variable for each model tested was presence/absence of Sooty Oystercatchers. Sample size (number of rocky shores assessed) = 8. Also note that the two species of barnacles have been combined for analysis, as have the two species of nerites and two species of limpets.

**Table 2.4**: Physical characteristics of islands and reefs within northern NSW.

| | Number Sooty pairs (density) | Historic record of Sooty breeding | Offshore distance (km) | Area (ha) | Elevation (m) | Soil Veg | Marine Park Protection | Historic Breeding Species |
|---|---|---|---|---|---|---|---|---|
| Sawtell Island | 1 (0.33) | Y | 0.1 | 3 | 5 | Y | N | 1, 2 |
| Korffs Islet | - | P | 0.6 | 1 | 16.4 | Y | N | 2, 3 |
| Muttonbird Island | 1 (0.13) | P | 0.5 | 8 | 45 | Y | Y | 1 |
| Little Muttonbird | - | P | 0.3 | 1.8 | 5 | Y | Y | - |
| Split Solitary | - | P | 2.5 | 4 | 40 | Y | Y | 1 |
| South Solitary Isl. | - | - | 7.8 | 11 | 28 | Y | Y | 2, 3 |
| South West Sol. Isl. | 1 (0.15) | P | 2 | 6.8 | 15 | Y | Y | 1 |
| Flat Top Point | 1 (0.40) | - | 0.1 | 2.5 | 6 | Y | Y | - |
| Woolgoolga Reef | - | - | 0.6 | 2 | 3 | N | Y | - |
| North West Sol. Isl. | 1 (0.53) | Y | 7 | 1.9 | 20 | Y | Y | 3 |
| North Rock NR | - | P | 2.4 | 4 | 15 | N | Y | 1, 3 |
| North Solitary Isl. | 1 (0.11) | Y | 12 | 9 | 58 | Y | Y | 1, 3 |
| North West Rock | - | - | 11 | 2 | 5 | N | Y | - |
| Shingle Break | - | - | 0.4 | 2 | 3 | N | Y | - |

Note: elevation of islands and historical records of breeding birds were obtained from the following sources: Lane 1974, 1975a, 1975b, 1976; Morris 1975a, 1975b; Roberts 1975; Swanson 1976; Holmes 1976. Distances offshore and area were determined with the use of maps; the presence of soil and vegetation was determined during site visits, and zoning information was obtained from the NSW Marine Park Authority (2006). Historic breeding species codes: 1 *Puffinus pacificus*, 2 *Larus novaehollandiae*, 3 *Sterna bergii*. Density = number breeding pairs per area (ha). Other codes: Y = yes, N = no, P = possibly.

Silver Gull density was generally low (< 20 individuals) on all islands with the exception of South Solitary and North Solitary where > 2,000 and > 200 individuals were recorded respectively during 2004. An estimated 500 Crested Terns (*Sterna bergii*) were also recorded on each of these two islands during 2004, but were rare on other islands. Other species to use the islands included Pied, Little Pied, Little Black and Great Cormorants (*Phalacrocorax varius*, *P. melanoleucos*, *P. sulcirostris* and *P. carbo*) and the Reef Heron (*Egretta sacra*). Other island breeders included a pair of Eastern Osprey (*Pandion cristatus*) currently breeding on North West Solitary Island, and a reported breeding population of 12,400 Wedge-tailed Shearwaters (*Puffinus pacificus*) on Muttonbird Island (Floyd and Swanson 1982).

Generalised linear modelling indicated that two models were supported as the best predictors of suitability of islands for nesting, both included the presence of soil and vegetation and one included reduced numbers of Silver Gulls (Table 2.5). Both had a good weight of evidence, however, the best model for predicting the occurrence of breeding included soil and vegetation only and this variable was included in all but one model with an $\Delta AIC_c$ of less than 10. Other factors such as island size, distance offshore and elevation had little support.

**Table 2.5**: Summary of model analysis with various combinations of factors (islands characteristics) as predictors for suitability of islands for nesting (n=14).

| *Modelled Predictor Variables* | *AIC* | *AICc* | *$\Delta AIC_c$* | *Akaike weight* |
|---|---|---|---|---|
| Soil and vegetation | 21.04 | 21.373 | 0.000 | 0.385 |
| Soil and vegetation, gull | 21.139 | 22.229 | 0.856 | 0.251 |
| Soil and vegetation, protection | 22.893 | 23.983 | 2.610 | 0.104 |
| Soil and vegetation, gull, protection | 21.978 | 24.378 | 3.005 | 0.086 |
| Soil and vegetation, gull, area | 22.923 | 25.323 | 3.950 | 0.053 |
| Soil and vegetation, gull, elevation | 23.125 | 25.525 | 4.152 | 0.048 |
| Gull | 25.891 | 26.224 | 4.851 | 0.034 |
| Soil and vegetation, gull, area, elevation, protection | 19.334 | 26.834 | 5.461 | 0.025 |
| Soil and vegetation, gull, area, elevation | 24.554 | 28.994 | 7.621 | 0.009 |
| Soil and vegetation, gull, area, elevation, protection, isolation | 19.57 | 31.57 | 10.197 | 0.002 |
| Soil and vegetation, gull, area, elevation, protection, tern | 20.291 | 32.291 | 10.918 | 0.002 |
| Soil and vegetation, gull, area, elevation, protection, tern, isolation, | 21.16 | 39.827 | 18.454 | 0.000 |
| Soil and vegetation, gull, protection, elevation, isolation, area, tern, shearwater | 22.882 | 51.682 | 30.309 | 0.000 |

## 2.5 Discussion

### *2.5.1 Population trends*

During the late 1980s it was estimated that there were only 20 Sooty Oystercatchers in northern NSW (Lane 1987). By the 1990s, the estimate had increased to 40 individuals (Smith 1991). Biannual counts on each section of coast during 1996, 1998 and 2000 then estimated 58, 34 and 60 (average 50) birds respectively, suggesting an increase in numbers (unpublished data, Australasian Wader Study Group). However, methods varied between studies and past counts were probably under-estimates due to limited coverage. Additionally, estimates were compiled from counts spanning many years from few locations. The latter counts, on the other hand, were coordinated and undertaken over short periods of time during each survey year over the entire stretch of coastline. The current study found estimates of 45-59 birds (average 52). Compared to the most recent more reliable counts it appears that the population has remained fairly consistent since at least 1996.

Although a decline had been recorded for some Tasmanian locations (Newman and Park 1982), a trend of population stability was subsequently reported for those same locations (Hewish 1990). Similarly in Queensland a decline may have occurred (Hewish 1990), but more recent reports suggest a possible increase (Harding 2004). Regular long-term counts undertaken in Victoria on the other hand, indicate a steady increase over the past 25 years (Hansen *et al.* in prep). However, wide fluctuations in seasonal and annual counts are often reported (e.g. Newman and Park 1982, Holmes 1990, Weston *et al.* 1995, Harding 2004), probably due to local movements, but also possibly due to sporadic count effort. Such fluctuations mean that obtaining accurate population estimates for the Sooty Oystercatcher is often difficult, as is determining their status. This highlights the need for coordinated long-term counts over large sections of the Australian coastline.

Density of Sooty Oystercatchers along the northern NSW coastline (0.32 birds $km^{-1}$) is similar to that reported for some sections of the Victorian coast (Weston *et al.* 1995) and the southern NSW coast (breeders = 0.45 birds $km^{-1}$, Keating and Jarman 2006), but much lower than those reported for Kangaroo Island (South Australia), Flinders Island, King Island and western Tasmania (Weston *et al.* 1995).

### *2.5.2 Breeding pairs*

Although the number of Sooty Oystercatchers fluctuated, the small breeding population of only 12 birds remained constant between years. Historic data indicate that although Sooty Oystercatchers occurred on almost all islands, islets and rocky outcrops in the study region (Lane 1974, 1975a, 1975b, 1976, Morris 1975a, 1975b, Roberts 1975, Swanson 1976, Holmes 1976), breeding had only been observed on a few islands (Table 2.4). Now breeding is confirmed on North Solitary, North-west Solitary, South West Solitary, Sawtell, Muttonbird Island and Flat Top Rock. In addition, Plover Island is a new possible breeding site. Although this represents an increase in known breeding pairs since the 1970s-1990s, again, this is likely to be an artefact of greater search effort. However, an increase in breeding pairs (from 16 to 21 pairs between 1994 and 2003) was recorded on islands off the south coast of NSW (Smith *et al.* 2002 c.f. Keating and Jarman 2003).

Nesting density on the south coast where the breeding population has included 78 pairs along 350 km of coast has been up to three pairs/ha on nesting islands (Jarman and Keating 2004, 2006). Similarly, the near-threatened African Black Oystercatcher (*H. moquini*) has also been reported at a density of up to five pairs/ha (Cooper *et al.* in Hockey 1996). Both the Sooty Oystercatcher and American Black Oystercatcher (*H. bachmani*) may nest only 50 – 100 m apart (Wakefield and Robertson 1988, Hazlitt 2001). When oystercatchers occur at high densities, competition is intense and vacant nesting territories are filled rapidly (Ens *et al.* 1996). Although there was a possible increase in breeders in the current study, density on the north coast remains quite low (0.11 – 0.53 pairs/ha) with only one pair per island used for nesting.

### *2.5.3 Foraging habitat*

The availability of both feeding and breeding sites has been suggested to govern Sooty Oystercatcher populations (Lane 1987, Chafer 1993). In northern NSW Sooty Oystercatchers are only infrequent visitors where there are no offshore islands for breeding and few rocky shores for feeding. Areas with many rocky headlands, near-shore reefs and short sand/gravel beaches provided optimal foraging habitat for immature and non-breeding birds. Offshore islands, small near-shore islands and reefs, rocky headlands and short gravel beaches provided the main breeding locations. Juveniles dispersed to two primary areas: Woody Head/Clarence River and Diggers Camp/Wooli as previously noted, post-fledging January – April (Gosper 1983, Gosper and Holmes 2002). Young African Black Oystercatchers have previously been shown to use discrete nursery regions where no breeding occurs - a first for such behaviour (Hockey *et al.* 2003); our observation, of another southern hemisphere oystercatcher species exhibiting such behaviour, would be the second.

Sooty Oystercatchers choose to forage in areas with a good degree of tidal wash, the lower tidal zone where oysters, nerites and Neptune's necklace were common, whereas the drier upper zone (supra-littoral), with higher densities of *Littorina*, are avoided (Witman *et al.* 2001). Consequently, within a region of general suitability (sections of coastline dominated by wide tidal platforms) many locations are suitable as feeding habitat. Previously, intertidal areas that were wider and less steep, rather than those with more abundant prey have been shown to be important for Eurasian (*H. ostralegus*) and American Pied Oystercatchers (*H. palliatus*) (Nol 1989, Ens *et al.* 1992).

Interestingly, limpets, which were consumed at all sites, did not appear among the best models. It is possible that predator prey interactions may explain this; while birds respond to prey density (use areas with high prey abundance), prey density is also altered as a result of predation pressure by birds (Begon *et al.* 1996). Consequently, shores devoid of birds have similar prey densities to those with reduced densities resulting from predation. Individual specialization by oystercatchers on certain prey species at the various sites may weaken model predictions. Although a wide variety of prey species are consumed by oystercatchers, generally few items account for the majority of prey consumed by most individuals. Furthermore, diet fluctuates in space and time (Hockey and Underhill 1984, Hockey 1996, Ens *et al.* 1996, Hulscher 1996, Zwarts *et al.* 1996a, 1996b).

### *2.5.4 Nesting habitat*

Sooty Oystercatchers typically nested on islands with few Silver Gulls, that had a soil layer rather than just exposed rock, and that were vegetated. Sites contining soil and vegetation tended to be larger islands (including measures of both hectares and elevation). Whereas, some small, low islands did not have a soil layer and were washed over during storms, large tides and big swells, and therefore, would pose a risk to eggs and chicks. Silver Gulls are increasing rapidly in coastal Australia (Priest *et al.* 2002) and may compete and interfere with other species as well as preying on eggs and chicks (Dann 1979, Hulsman 1984, Dann 1987, Egan 1990, Smith 1991), hence explaining the avoidance by oystercatchers.

In accordance with others (Vermeer *et al.* 1992, Rusticali *et al.* 1999, Keating and Jarman 2003), we found that the Sooty Oystercatchers did nest on islands connected to the mainland by sandbars and man-made rock-walls as well as those some distance (12 km) offshore. Furthermore, human access did not appear to reduce the likelihood of oystercatchers breeding on an island (Burger 1981, Pfister *et al.* 1992, Burger 1994, Lindberg *et al.* 1998, Vermeer *et al.* 1999); although human habitation might.

### *2.5.5 Breeding biology*

The period of egg-laying was short and matched that reported for the south-east of Australia, (Marchant and Higgins 1993) and specifically for NSW (Morris *et al.* 1981 in Smith 1991). Sooty Oystercatchers laid two eggs as previously found by Lauro and Nol (1995a) and Smith *et al.* (2002). From limited data hatching success was slightly higher than that reported by Lauro and Nol (1995a), but similar to that reported by Marchant and Higgins (1993). Unlike previous reports (Lauro and Nol 1995a, Smith *et al.* 2002), in the current study it was found that two chicks could be raised successfully by Sooty Oystercatcher pairs.

Unfortunately neither this nor previous studies have found any evidence on the cause of egg or chick loss (Lauro and Nol 1995a). Avian predators, such as Whistling Kite (*Haliastur sphenurus*), White-bellied Sea Eagle (*Haliaeetus leucogaster*) and Swamp Harrier (*Circus approximans*) have previously been suspected of causing chick and adult loss in Australia (Lane 1987, Minton 1989, Marchant and Higgins 1993, Weston *et al.* 1995), while gulls, ravens and rats have been suggested as possible nest predators (Wakefield 1988, Lauro and Nol 1995a). Although Pacific Gulls (*L. pacificus*) do not occur in the current study region, Silver Gulls occur on most islands, though not where Sooty Oystercatchers bred, possibly suggesting avoidance. Rats (*Rattus rattus* and *R. lutreolus*) are also possible predators of eggs on at least one of the islands (Muttonbird). Dogs prey on eggs and chicks of numerous ground-nesting species (Retallick and Bolitho 1993, Miller *et al.* 2001, Weston 2001, Baird and Dann 2003), and are possible predators on at least the two most accessible nesting islands (Flat Top and Sawtell).

### *2.5.6 Productivity*

Although the above mentioned studies document clutch sizes, hatching success and fledging success (Marchant and Higgins 1993, Lauro and Nol 1995a) Sooty Oystercatcher productivity has rarely been documented. Consequently, no species-specific productivity comparison can be made. However, compared to most oystercatcher species, including the Australian Pied (see Chapter 3) the estimated productivity during this study, although based on a small number of nests, seems quite high (Ens *et al*. 1992, Hockey 1996, Braby and Underhill 2007), although is comparable to the African Black Oystercatcher (*H. moquini*) that has also been reported to produce 0.87 fledglings per pair (Calf and Underhill 2002). Nonetheless, as nest visits were infrequent and breeding pairs may have been missed productivity may have been over-estimated.

### *2.5.7 Implications for management*

Overall counts suggest stability and indicate no need for a revision of status. However, declines of long-lived species often take years to become evident (Garnett 1992, Davis *et al.* 2001), and given that suitable nesting habitat is unoccupied and that birds occur in low densities on nesting islands, it is likely that the population is below carrying capacity. Numbers for the region are low, distribution is patchy and few breeding pairs are present, therefore recovery potential after any decline remains poor, despite apparently high reproductive success.

There is a need for accurate long-term coordinated counts, which include all islands and coastlines, even those that have historically not had breeding birds. Given that a detailed survey has now been undertaken, any increase in breeding pairs will be representative of an increase. Furthermore, leg-flagging programs should be implemented to obtain data on age at first breeding, survival to breeding age, adult survivorship, movements and dispersal so that a comprehensive assessment of the population can be made. Ideally, leg-flagging should be conducted within each state, where numbers are known to be large. Continued monitoring of reproductive success is also required to determine productivity of larger populations.

Nesting islands are generally protected owing to their isolation from the mainland and inclusion within a Marine Park. Ensuring that these islands remain predator-free may be crucial given the small number of breeding pairs in the region. If however, numbers were to increase, data also suggest that controlling Silver Gulls on Korffs Islet may also then allow Sooty Oystercatchers to breed there. Breeding near-shore islands that are currently accessible by foot should also be better protected during breeding, to ensure that people and their pets do not disturb nesting and chick brooding oystercatchers.

Also, although most Sooty Oystercatchers nest off-shore, foraging areas on mainland coastlines are often used and are subject to numerous threats including human disturbance and sea-level rise. The impact of disturbance on foraging behaviour also warrants research, as although breeding success appears high, factors affecting adult and immature survivorship also may limit populations.

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# CHAPTER 3

Population trends and habitat use of Australian Pied Oystercatchers (*Haematopus longirostris*) inhabiting beach and estuarine habitats in sub-tropical NSW


## Abstract

The Australian Pied Oystercatcher (*H. longirostris*) is listed as a threatened species in New South Wales. However, a paucity of information exists on the abundance, population structure, distribution, and ecology of the species in NSW. Australian Pied Oystercatchers were counted and habitat was assessed along an 186 km stretch of coastline between the Richmond River (28°50'S, 153°31'E) and Bonville Creek (30°16'S, 153°05'E), northern NSW, between 2003 and 2005. An estimated 129 Australian Pied Oystercatchers were present in 2003 of which 70% were breeding birds. Two years later, only 112 birds were present. Declines occurred in breeding pairs (17%), non-breeding territory holders (5%) and floaters (33%). Although the population has apparently grown over past years (1990-1998), a rapid downturn since the late 1990s is evident, with a net decline of 13% between 2003 and 2005. Adult mortality was estimated at a minimum of 10% annually. Predictors of Australian Pied Oystercatcher presence, included: high densities of food supply, bivalve molluscs (*Donax deltoides*), soldier crabs (*Mictyris longicarpus*) and polychaete worms; beach morphology (greater length and gentle slope) and estuary characteristics; floral characteristics of dunes; and level of human disturbance. The majority of birds occurred on ocean beaches to the north of the Clarence River, while only 39% of pairs occupied estuaries in the south. Practices impacting on prey density, such as the harvesting on the beach bivalve (*D. deltoides*) should be actively managed as the large majority of Australian Pied Oystercatchers in this region rely heavily upon this resource for survival. The removal of noxious plant species from dunes should be done carefully and may need further investigation. Vehicle access points along with disturbance caused by humans and their pets must be minimised in an effort to increase oystercatcher numbers and survivorship of the species.



**Key words**: Australian Oystercatchers, habitat use, breeding sites, beach-nesting, estuary-nesting, population trends.

## 3.1 Introduction

The Oystercatchers (Haematopodidae) occupy almost all continents of the globe. These large shorebirds are long-lived with some species reported to live up to 40 years of age (Ens *et al.* 1996, Hockey 1996). Breeding generally commences between four and six years of age, or even later in some populations (Newman 1992, Marchant and Higgins 1993, Hockey 1996) and a life-long pair bond is generally formed between partners, although divorce has been documented (Harris *et al.* 1985). Birds exhibit a high level of site fidelity and occupy traditional nesting territories. Although the breeding season extends over four to six months, only one brood will be raised per season (Hockey 1996). Such traits place the species at risk in changing environments, as small changes in survival rate may have large consequences for populations (Davis *et al.* 2001).

The Australian Pied Oystercatcher (*Haematopus longirostris*) is an endemic resident of temperate and tropical Australasia, using open ocean beaches, sand-spits, sand islands within estuaries and occasionally adjoining fields for both breeding and feeding (Marchant and Higgins 1993, Minton 1999). The species occurs in low density throughout its range, with highest counts recorded from Victoria, South Australia and Tasmania (Lane 1987, Watkins 1993, Weston and Heislers 1995, Minton 1997). The species is generally sedentary, particularly during breeding when birds are extremely territorial (Lane 1987, Marchant and Higgins 1993, VWSG unpublished data). However, local movements are regular and occasional long-distance movements have been recorded. Foraging on intertidal shores, primary prey items include bivalve molluscs, polychaete worms and crustaceans. Nests are simple scrapes just above the high water mark on the sand or soil in which two to four camouflaged eggs are laid. Lining of twigs, shell fragments, pebbles or vegetation may be used to further camouflage eggs (Lane 1987, Lauro and Nol 1993, Marchant and Higgins 1993). Breeding generally occurs from June to September in the tropical north and September to January in the temperate south (Newman 1992, Marchant and Higgins 1993, Lauro and Nol 1993).

As a result of perceived declines in both distribution and abundance, Australian Pied Oystercatchers are listed as *Vulnerable* in New South Wales (Schedule 2 of the NSW *Threatened Species Conservation Act 1995*). The NSW population has been estimated to be as low as 250 individuals (Watkins 1993). Declines have been attributed to low breeding success as a result of various threats including: human disturbance to feeding, roosting and nesting sites; destruction of nests, eggs and chicks via trampling by people, horses or dogs, or crushing by vehicles; predation by foxes, feral and domestic dogs and cats; habitat loss due to development; pollution of estuarine and coastal areas; tidal flooding (Smith 1991, Marchant and Higgins 1993, Watkins 1993, Priest *et al.* 2002); and in the long-term by rising sea levels due to climate change (Burger 1994, Jones *et al.* 2004, Wormworth and Mallon 2006).

Despite their listing, Australian oystercatchers have received little attention compared to their much studied international counterparts. Few studies have dealt with the ecology of the species, and a paucity of information specific to New South Wales exists. Previous studies have focused on counts and movements through long-term banding of Australian Pied Oystercatchers in Victoria, Tasmania and Western Australia (Minton 1997, Kraajijeveld-Smit *et al.* 2001, Kraajijeveld-Smit *et al.* 2004, VWSG unpublished data). It is only recently (2006) that alpha-numeric colour flagging of Australian Pied Oystercatchers has taken place in an effort to determine movements in NSW, although many birds were banded between the mid 1980s and 2006 with numbered metal bands. (Banding has been occurring since the mid-1980s and fairly intensively during the 1990s, although flags were not used until 2006 (G. Clancy pers. comm.). With a recently proposed management strategy to be developed for the species in northern NSW (DoL 2007), details on the distribution and ecology of the species were required, along with up-to-date counts. Thus, the aims of this work were to: a) provide an estimate of population size; b) determine the current distribution, including breeding sites, in northern NSW; c) examine population trends using current and historic count data; d) identify habitat features associated with the presence of oystercatchers; e) through the use of modelling, determine whether additional nesting habitat was available to provide potential for growth; and f) provide guidance for future management.

## 3.2 Study area

Surveys were undertaken between the southern wall of the Richmond River (South Ballina Beach, 28°50’S, 153°31’E) and Bonville Estuary (Sawtell, 30°16’S, 153°05’S) in northern NSW (Figure 3.1). This 186 km stretch of coastline comprises both short and long stretches of intermediate beaches (Short 2000), with a gently sloping gradient, wide face, large surf zone and fine sand particles, through to almost reflective beach states, comprising steep often narrow beach faces, small waves and coarser sediment (Short 2000). South Ballina Beach, within the study region, is the second longest (31km) beach in NSW (Short 2000). Interspersed are rocky headlands varying in aspect and exposure with intertidal rock platforms. Also interspersed are 13 tidal estuaries varying in catchment area, length, vegetative components, water flow and sediment movements. Accessibility and disturbance to beaches and estuaries varies. Many NSW beaches have restricted vehicle access, however, at South Ballina Beach, Ten Mile Beach and Station Creek vehicles are not restricted and high seasonal usage occurs, which peaks during school holidays (late September- early October and late December–January), coinciding with the oystercatcher breeding season. However, in recent years vehicles have been prohibited from driving south of the access at Station Creek, in an effort to protect the Little Tern. There are three authorised vehicle access points along South Ballina Beach; South Ballina (with a holiday park directly behind dunes), Patches Beach (with a small township directly behind dunes) and Boundary Creek (backed by farmland).

The coastline is subject to mean tidal heights of 1.2-2 m. Average air temperatures range between 12°C during the winter and 21-24°C during the summer. Seasonal rainfall is variable with an annual average of 1200-1600 mm (BoM 2005).

## 3.3 Methods

### *3.3.1 Large-scale distribution and abundance*

Surveys were undertaken seasonally throughout the years 2003 and 2005 to determine an accurate population estimate of Australian Pied Oystercatchers. During 2004, owing to logistical time constraints, locations were surveyed less frequently and volunteers assisted where possible. Beaches, headlands, near-shore islands and the lower reaches of estuaries within the region were included. Surveys were either by foot where possible or 4WD, or in the case of islands, by boat. Searches were conducted during low tide on consecutive days to minimise disturbance, recounts and any over-estimation of abundance. Location and abundance of birds were recorded. Observations were made with the use of 8x10 binoculars and a 40x magnification (Kowa) viewing scope. Potential breeding pairs were identified during winter and verified by spring and summer when pairs became more sedentary within territories. Breeding was confirmed by the presence of eggs, and non-breeding pairs that were territorial were also identified during this period. Birds that were not breeding or territorial, and moved around locally were also identified as “floaters”. Although not territorial, floaters tended to occur in small groups in a range of regular locations, and were easily identifiable due to low numbers. Due to the essentially linear habitat and strong site fidelity, particularly during breeding, counts are considered reliable.

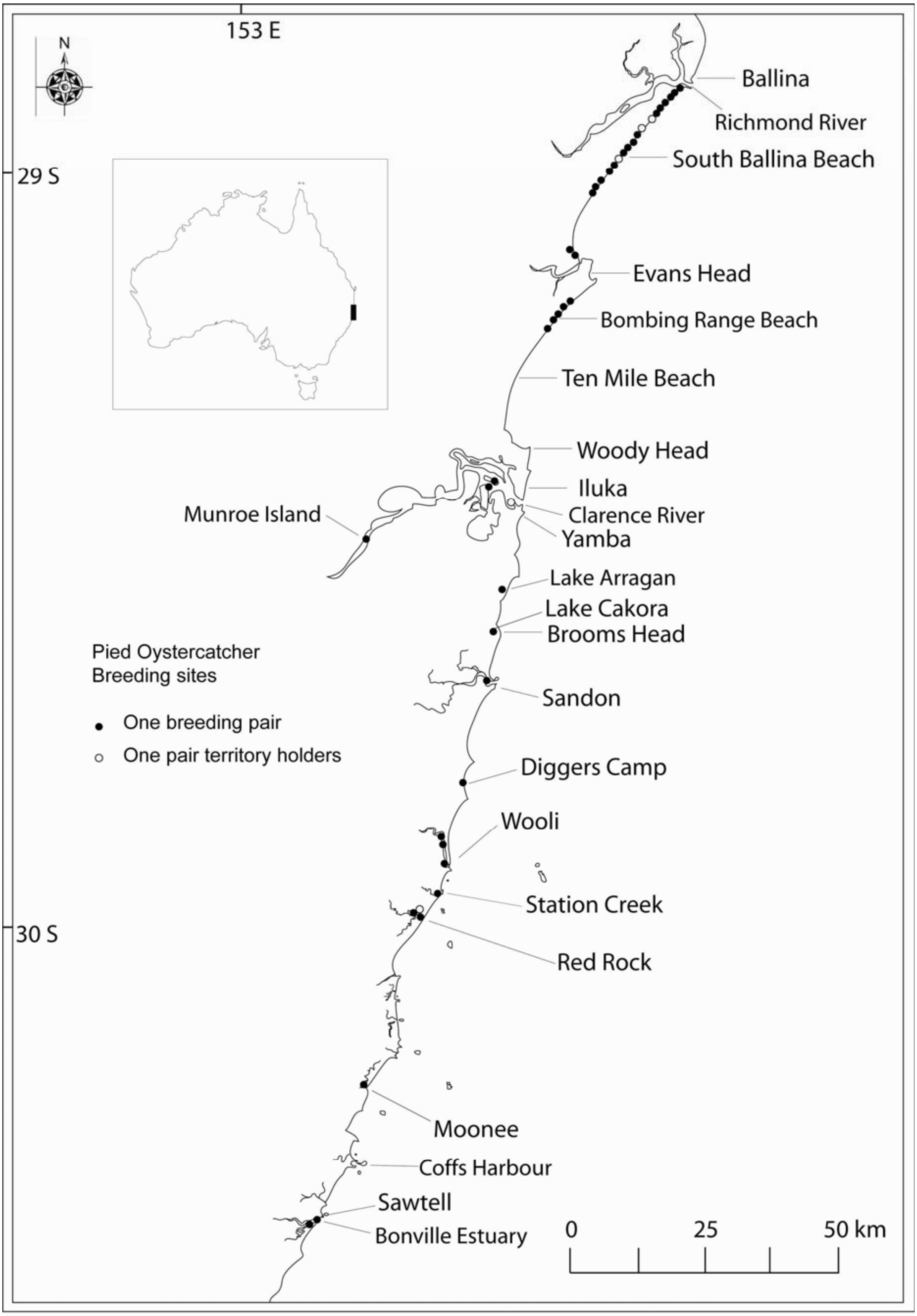


**Figure 3.1**: Distribution of breeding and non-breeding territory holding Australian Pied Oystercatchers in northern NSW, between Bonville Estuary and the Richmond River.

### *3.3.2 Small scale breeding distribution – South Ballina Beach*

During September, October and November 2005, Australian Pied Oystercatchers at South Ballina Beach were closely monitored. The number of pairs and their specific nesting locations were recorded. Behaviour of adults was recorded as was the number of banded individuals forming breeding pairs. Some juvenile oystercatchers within northern NSW have previously been banded with metal bands (numbers engraved) and continued to be banded concurrent to this work by Greg Clancy. All functional territories were identified, territory size was estimated as the total area used by a pair for nesting and foraging. Pairs were generally monitored every day for a two-week period, alternating two-weeks on, two weeks off over the breeding period.

### *3.3.3 Habitat assessment*

Eleven randomly chosen beach sites were assessed, including six where birds were present and five where they were not, across all seasons of 2003. Three estuary sites were also assessed seasonally (two with birds, one without). Each site was classified as either isolated or close to a town for analysis purposes. Physical and biological habitat characteristics were measured at beach sites. Measurements were taken of air temperature, wind speed and direction, rainfall, % cloud cover, beach width and slope, dune height, sediment type and fore-dune width (as this is often the zone used for nesting).

Beach and estuary macrofauna were sampled using a stratified nested design. Three random quadrats (33 cm x 33 cm x 15 cm deep) were placed within each of three sites, 100 meters apart, at each of the 14 locations, during each of four seasons. A total of 504 core samples were taken during 2003. Using a shovel, sand was then exhumed and placed onto a sieve of 1 mm mesh before being agitated in ocean/estuary water, thus removing the sediment. Prey species retained on the mesh were identified *in situ*, counted, and returned to the sediment. Beach bivalves, commonly known as pipis (*Donax deltoides*), the main food source, were measured in millimeters to the first decimal with vernier callipers.

Vegetation was measured (% cover) at each of the 11 beach locations, within four randomly placed $1m^2$ quadrats on the dune and repeated on the fore-dune area. Beach slope was determined using a dumpy level, which allowed height measurements to be taken at both high and low tide marks, and the height difference determined. Slope of the beach was then calculated using these figures along with beach width measurements, using: Sin θ = Opposite divided by Hypotenuse. Characteristics of all 13 estuaries, including catchment area, waterway area, mangrove area, seagrass area, saltmarsh area and river length, within the study region were gathered (DLWC 1999) and tabulated.

### *3.3.4 Statistical analysis*

An information-theoretic approach using generalised linear regression analysis was undertaken to determine which biological and physical factors were important in predicting the presence or absence of Australian Pied Oystercatchers at beach and estuary sites. Candidate models, representing competing hypotheses, were tested; lending support to a particular hypothesis depending on which model was identified as best (Johnson and Omland 2004). Using such models it is then possible to predict where species may occur, based on where certain habitat features (or the combination of features) occur. Analysis was conducted using the statistical program R (Development Core Team 2006), as described in Chapter 2.

## 3.4 Results

### *3.4.1 Abundance*

An estimated 129 Australian Pied Oystercatchers occurred between the southern wall of the Richmond River and Bonville Estuary at the start of the 2003 breeding season. Territory holding adults made up 66.7% of the total population (86 birds) and included 41 pairs, a single bird and a breeding trio (Totterman and Harrison 2007, see Appendix A) (Table 3.1). Floaters accounted for the remaining 43 birds (Table 3.2). By the beginning of the breeding season of 2005, there were a total of only 112 birds. This included 41 territorial pairs, (including the third bird interacting with one of those pairs, two other single residents, 83 birds) and 29 floaters. Less thorough searches in 2004 also yielded 88 territorial birds and 36 floaters (total 124 birds). Not all resident pairs attempted to breed in any year (Table 3.2). The number of pairs (including trio and singles) occupying territories fell from 41 during 2003, to 39 in 2004 and then to 34 by 2005. Hence, a decline occurred for all cohorts, including the number of adults to hold a territory (-4.7%) the number of breeding pairs (-17%) and the number of floaters (-32.6%), between the years 2003 and 2005 (Table 3.1 and 3.2). However, territorial adults were lost south of the Clarence, five birds from estuaries, three birds from beaches, while they were gained in the north, i.e. two pairs on beaches. Conversely, floaters were gained in the south (up 15 birds) and lost in the north (down 19 birds) (Table 3.1).

Fifty-one chicks were identified to have fledged within the region between 2003 and 2005, with the majority of these produced by estuary pairs (thesis chapter four). However, juvenile survival to first year was unknown for the period, and is probably lower than that of adults, thus the number of recruits would have been less. Dead birds were found at South Ballina (dead male replaced by another within 24 hours of the vacancy, dead female replaced 10 days after her loss) and others simply disappeared (one bird from trio lost following 2003 season, mate from Lake Cakora lost before 2005 season, others lost from Ballina as indicated by new banded birds in pairs). While total numbers are not known, a minimum of 17 losses (10% p.a. of adults) can be confirmed over the two years (Table 3.1). Of these losses, six breeding adults were replaced by floaters at South Ballina Beach (as indicated by banded individuals) and two are suspected of being replaced at Red Rock, though they are not currently (2005) breeding.

### *3.4.2 Distribution (large-scale)*

Fourteen locations were used for breeding within the region (Figure 3.1). All birds north of the Clarence River (Yamba/Iluka) nested on open sandy beaches, whereas those to the south were generally estuary nesters, with pairs nesting as far as 11 km up river (Munro Island). As most birds occurred in the north, beaches were used for nesting by the majority of territorial pairs (20). Average density of beach nesting pairs between the Richmond and Evans Rivers was 0.65 pairs $km^{-1}$. South of Evans River only six pairs were beach nesters, 14 nested on islands, sand spits and low dunes within and adjacent to estuarine habitats and three pairs utilised both. In total eight of the 13 coastal estuaries within the study region were occupied by breeding oystercatchers (one to three pairs each) (Figure 3.1). Although many of these were known previously as breeding sites for many years (G. Clancy pers. comm.), Diggers Camp Beach, Moonee Estuary, Bonville Estuary (Sawtell), Lake Cakora, Lake Arragan and Munro Island have not specifically been identified as breeding sites in previous publications (Smith 1991). Average density for the entire survey region was 0.15 pairs $km^{-1}$ of coastline.

A large proportion of the non-breeding birds also occurred within the northern section of the region, from Ten Mile Beach to the Richmond River during 2003 (about 40%). However, most were no longer present in that region by 2005. Conversely, by 2005 floaters in the Wooli Estuary/Beach region had grown from four to 14 (Table 3.1), these floaters were fledglings that were observed to remain in the area following fledging from estuary nests in 2003, 2004 and 2005. These fledglings remained throughout the non-breeding season, and made frequent use of nearby beaches and estuaries for foraging. Small numbers of floaters also occurred periodically at other locations during the period of survey (Table 3.1).

**Table 3.1**: Breakdown of Australian Pied Oystercatcher numbers in northern NSW between 2003 and 2005, including numbers of fledglings and adult losses.

| Locations | Resident adults 2003 | Resident adults 2005 | Floaters 2003 | Floaters 2004 | Floaters 2005 | Fledglings 03-05 | Nett Loss |
|---|---|---|---|---|---|---|---|
| South Ballina Beach | 36 ▪ | 38 ▫ | 6 | 6 | 0 | 15 | 6 |
| Evans Head Beach | 4 | 4 | 2 | 0 | 0 | ? | - |
| Bombing Range Beach | 10 | 12 | 0 | 2 | 6 | ? | - |
| Ten Mile Beach | 0 | 0 | 17 | 7 | 0 | - | - |
| Woody Head | 0 | 0 | 2 | 0 | 0 | - | - |
| Clarence River/Estuary | 6 | 4 | 0 | 2 | 2 | 8 | 2 |
| **Sub-total North of Clarence River** | 56 | 58 | 27 | 17 | 8 | 23 | 8 |
| Angourie Beach | 0 | 0 | 2 | 2 | 2 | - | - |
| Munro Island/Estuary | 2 | 2 | 0 | 0 | 0 | ? | - |
| Lake Arragan/Estuary | 2 | 2 | 0 | 0 | 0 | ? | - |
| Brooms Head beach | 0 | 0 | 2 | 2 | 2 | - | - |
| Sandon Estuary | 2 | 2 | 0 | 2 | 2 | 2 | - |
| Lake Cakora/Estuary | 2 | 1 | 0 | 0 | 0 | 1 | 1 |
| Diggers Camp Beach | 2 | 0 | 0 | 0 | 0 | 1 | 2 |
| Wooli River Estuary | 6 | 4 | 4 | 7 | 14 | 10 | 2 |
| Station Creek Estuary | 2 | 2 | 0 | 2 | 0 | 3 | - |
| Red Rock Estuary | 6 | 6 | 2 | 0 | 0 | 7 | 2 |
| Arrawarra Beach | 0 | 0 | 2 | 0 | 0 | - | - |
| Moonee Estuary | 2 | 2 | 0 | 0 | 1 | 0 | - |
| Jetty/Boambee Beach | 0 | 0 | 2 | 2 | 0 | - | - |
| Coffs Creek/ Estuary | 0 | 0 | 2 | 2 | 0 | - | 2 |
| Boambee Estuary | 4 | 4 | 0 | 0 | 0 | 4 | - |
| **Sub-total South of Clarence River** | 30 | 25 | 16 | 19 | 31 | 28 | 9 |
| GRAND TOTAL | 86 | 83 | 43 | 36 | 29 | 51 | 17 |

Note: All locations between South Ballina Beach and Boambee Estuary were surveyed, however only those locations where Australian Pied Oystercatchers were recorded have been included. ▪ Number includes breeding trio, also single male territory holder. ▫ Number includes third bird disrupting a pair, also different single male from 2003, and the addition of another pair.

**Table 3.2**: Total number of Australian Pied Oystercatcher resident pairs (to hold a territory) in northern NSW between 2003 and 2005 and the number to actually breed in those territories during that period. The latter is also presented as a percentage of the total number to hold a territory

| | **2003** | **2004** | **2005** | **Trend** |
|---|---|---|---|---|
| Pairs holding territories | 43 ▪ | 44 | 41 ▫ | -4.7% |
| Breeding pairs | 41 | 39 | 34 | -17.1% |
| Percentage breeders | 95.3 | 84.8 | 80.9 | |

Note: ▪ Number includes breeding trio, also single male territory holder; ▫ number includes third bird disrupting a pair, also different single male from 2003, and the addition of another pair.

Following the breeding season, localised movement by adults was also noted between neighbouring beaches for beach nesting birds, and between beaches and estuaries for estuarine nesting birds. Banded individuals occurred at Red Rock (female banded there as an adult by D. Geering in 1985) and Sandon Estuary (male banded as a juvenile at Red Rock by G. Clancy in 1986, which later moved to Sandon) (G. Clancy pers. comm.), they were ~ 20 years old, thus were experienced breeders, having shown little movement at all from natal sites.

### *3.4.3 Distribution (small-scale)*

South Ballina Beach was identified as containing the highest density of breeding pairs (17), with neighbouring nests situated approximately 250 m apart. A clustering of pairs in the north and south of the beach occurred (Figure 3.2), leaving a gap in territories (of approximately 4 kilometres) surrounding the central vehicle access point at Patches Beach. This point had the highest recreational use by vehicles (Ballina Shire Council unpublished data) and was also most used by swimmers, sunbakers, fishermen and people walking with dogs off-leash (A. Harrison pers. obs.). In addition, resident pairs nearest to Patches access, both north and south, did not attempt to breed, leaving a pronounced gap in breeding territories of almost 5.5 km surrounding the town and vehicle/pedestrian access point. Hence, access points were avoided by oystercatchers.

Five pairs at South Ballina Beach also contained individuals with bands, all but one of which were located immediately adjacent to access points (Figure 3.2). The remaining banded bird was located at the southern fringe of the cluster of birds. Beyond that pair the shoreline is dominated by rocky habitat rather than wide sandy shores. Where bands were read, birds were identified as only four and five years old (B. Totterman and G. Clancy unpublished data). These banded birds made up 13.2% of the territory holders at this site.

### *3.4.4 Habitat assessment*

#### *Diversity and abundance of prey species*

Prey items available to Australian Pied Oystercatchers throughout the year included pipis (ranging in length from 0.1 cm – 6.6 cm), soldier crabs (*Mictyris longicarpus* and *Mictyris platycheles*, average 1.5 cm wide), polychaetes (average length 3.2 cm), isopods (average length 0.4 cm), amphipods (average length 0.6 cm), gastropods (average 0.9 cm wide) and other small crustaceans. Pipis, soldier crabs and isopods were most abundant during winter months, with densities decreasing progressively throughout spring, summer and autumn. The largest prey item found, the pipi, was most abundant at beach sites, with a patchy distribution. However when found in estuary sites, they occurred at high densities but were all <0.5 cm in length (those occurring on beaches were mostly approximately 5 cm). Estuary sites contained a greater density of soldier crabs, isopods and amphipods than beach sites (Figure 3.3a and 3.3b).

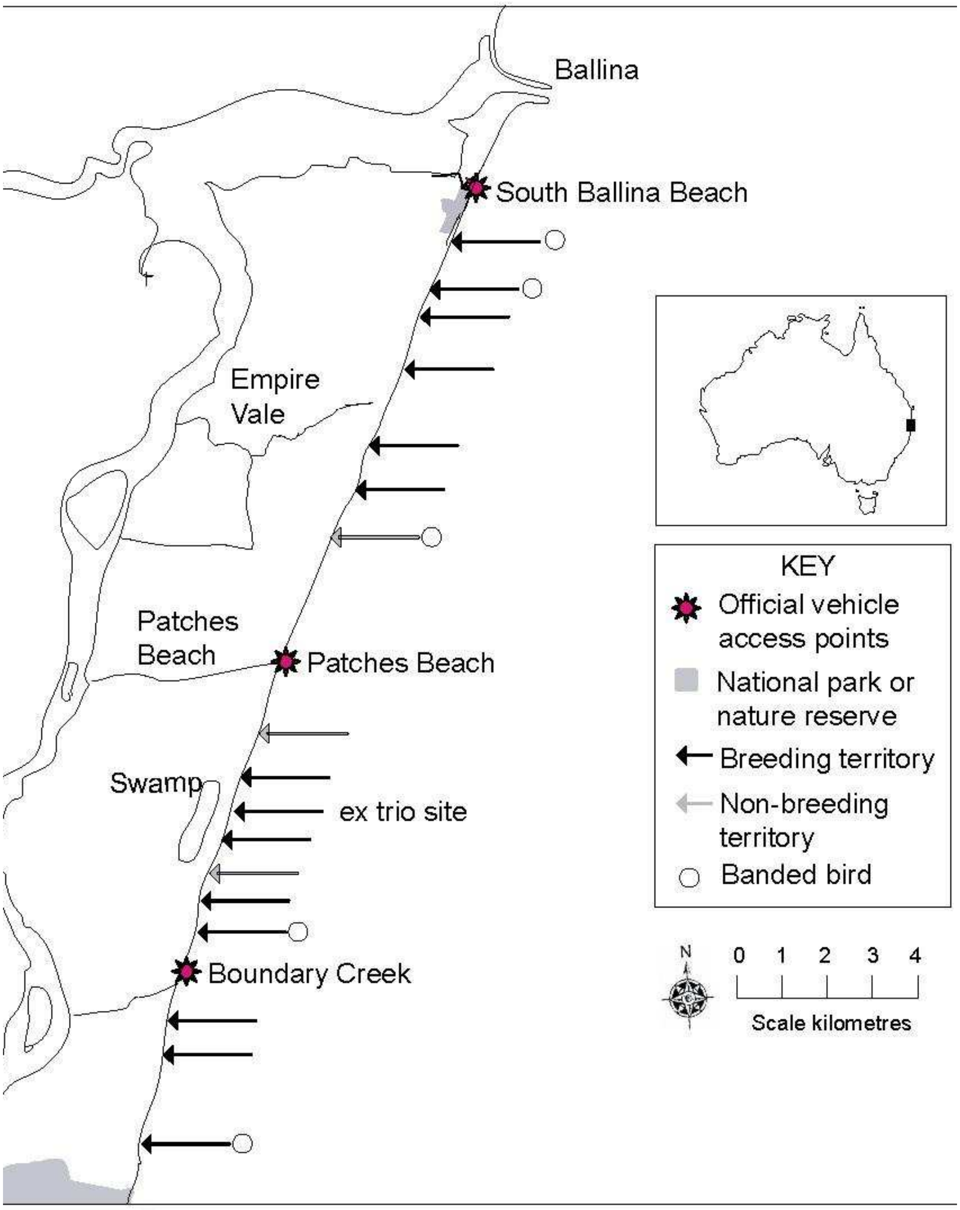


**Figure 3.2**: Location of Australian Pied Oystercatcher territories on South Ballina Beach.

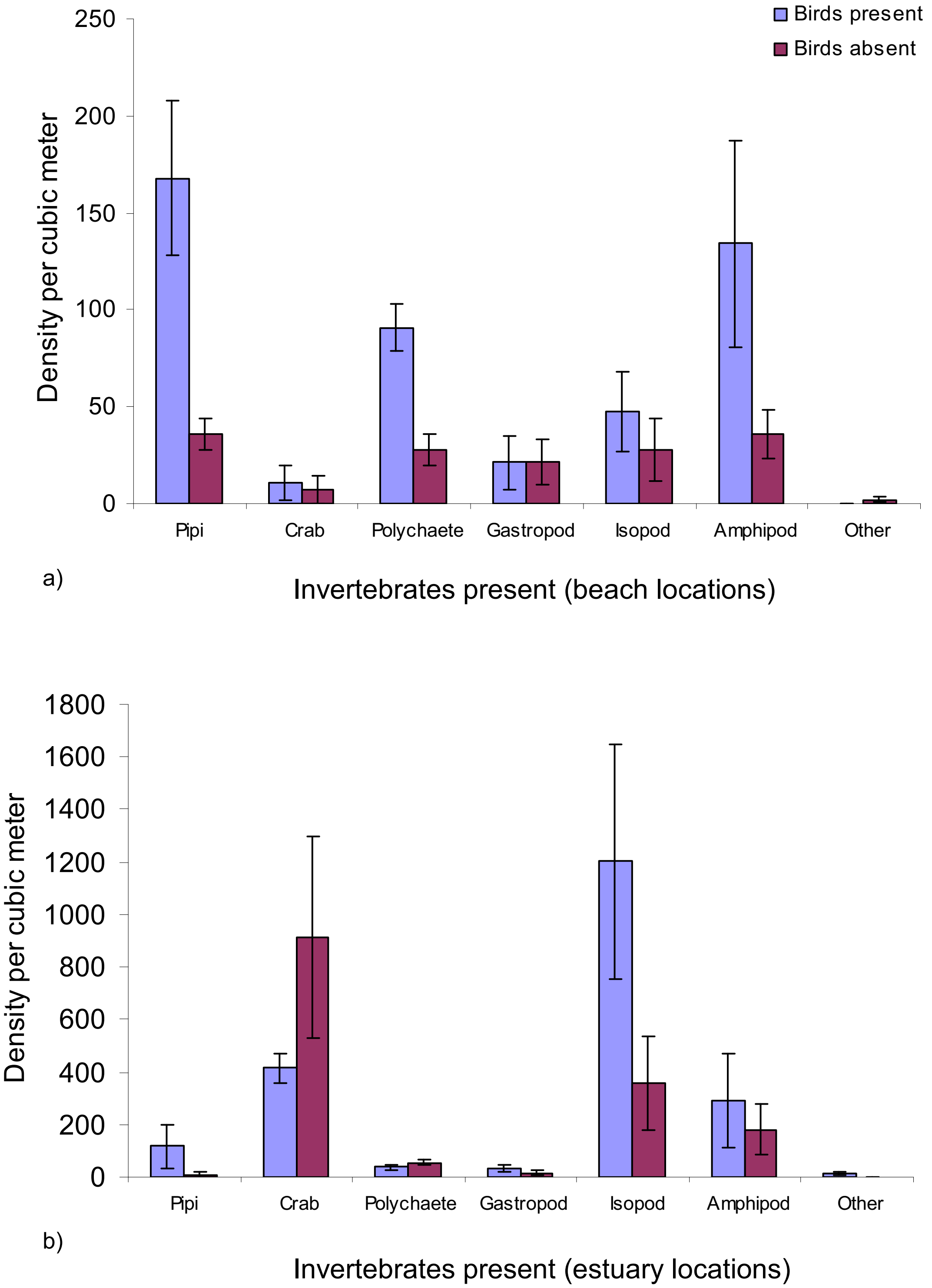


**Figure 3.3**: Density per cubic meter of sand of invertebrates found at a) beach and b) estuary habitat, where birds were either present (location n = 8) or absent (location n = 6). Note scale is different between a) and b).

Four models for the presence of Australian Pied Oystercatchers (at both beach and estuary sites) with $\Delta AIC_c$ of under 10 were identified (Table 3.3). All included the variables pipi, polychaete and soldier crab, which therefore likely influenced the presence of Australian Pied Oystercatchers. Oystercatchers were more likely to occur at sites containing high densities of pipis ($p = 0.016$), polychaetes ($p = 0.004$) and soldier crabs ($p = 0.018$, Table 3.3). Habitat type (beach or estuary), and season, were less powerful predictors of species presence at the large scale.

**Table 3.3**: Generalised linear regression results for sandy shore macrofauna variables as predictors of presence or absence of Australian Pied Oystercatchers.

| *Modelled Parameters* | *AIC* | *AICc* | *$\Delta AIC_c$* | *Akaike weight* |
|---|---|---|---|---|
| Pipi, polychaete, soldier crab | **53.969** | **56.369** | **0.000** | **0.610** |
| Pipi, polychaete, gastropod, soldier crab | 53.93 | 58.413 | 2.004 | 0.224 |
| Pipi, soldier crab, polychaete, isopod | 55.152 | 59.596 | 3.227 | 0.122 |
| Pipi, soldier crab, polychaete, isopod, gastropod | 54.212 | 61.712 | 5.343 | 0.042 |
| Pipi, polychaete, gastropod | 59.751 | 62.151 | 10.882 | 0.002 |
| Pipi, soldier crab, polychaete, isopod, gastropod, amphipod, shrimp | 55.07 | 73.736 | 17.137 | 0.000 |
| Season, pipi, soldier crab, polychaete, isopod, gastropod, amphipod, shrimp | 59.995 | 88.795 | 32.426 | 0.000 |
| Season, habitat type, pipi, soldier crab, polychaete, isopod, gastropod, amphipod, shrimp | 61.962 | 193.962 | 137.593 | 0.000 |

Note: The response variable for each model tested was presence/absence of Australian Pied Oystercatchers. Sample size (number of beaches and estuaries assessed) = 14.

Pipi length decreased from northern to southern locations. Regression analysis indicated that 76% of the variation in pipi length ($R^2$=0.7585) could be attributed to latitude (Figure 3.4), (one-way ANOVA $p = 0.024$). Pipi density however, was not significantly (one-way ANOVA, $p = 0.627$) correlated with latitude, rather density varied greatly among locations. However, pipis were not found on beaches with a slope of greater than 2.02°, where the sediment was very coarse i.e. those classified as more reflective than intermediate.

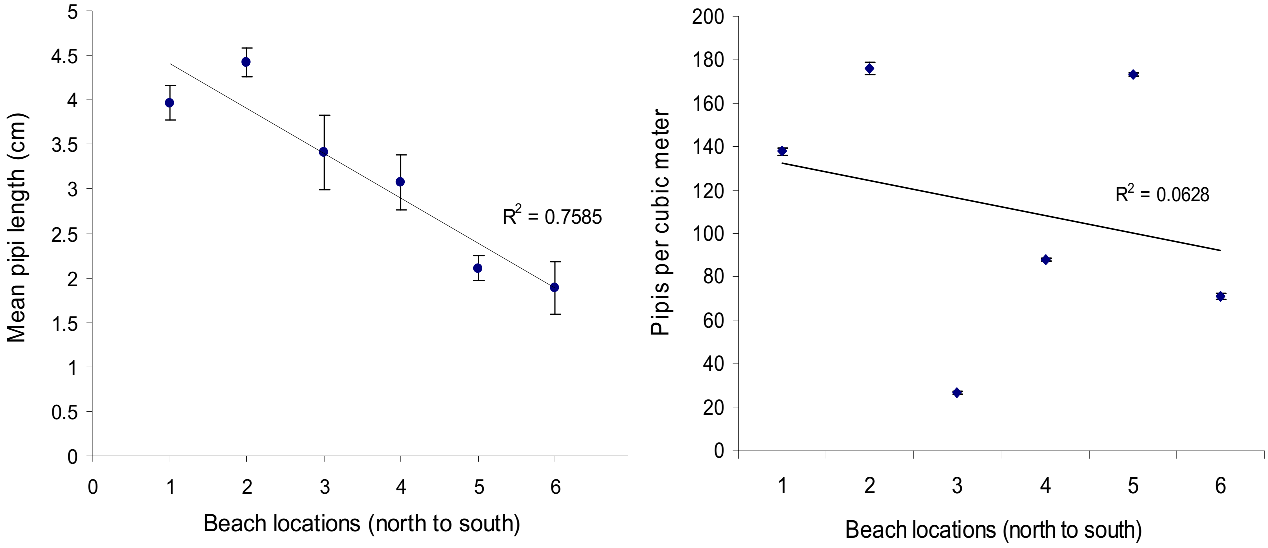


**Figure 3.4**: Regression plots of a) mean *D. deltoides* length (cm) and b) *D. deltoides* density (per metre squared) across beach location/latitude. Note: beaches are plotted on a north to south gradient. Location 1 = South Ballina Beaches combined, 2 = Ten Mile Beach, 3 = Iluka/ Pipi combined, 4 = Sandon Beach, 5 = Wooli Beach, 6 = Boambee Beach.

*Physical beach characteristics*

Best candidate models for the presence of the Australian Pied Oystercatcher, based on $\Delta AIC_c$ values and comparison of the Akaike weightings, included gentle beach slope, increased beach length, and increased isolation from towns (Table 3.4). Fore-dune width was also a significant factor, but was not included in the top model. Beaches occupied by oystercatchers had an average length of 19.27 km and a mean slope (ranging 0.06 – 4.28) of 1.22°. Beaches devoid of birds had an average length of 2.65 km, with an average slope (ranging 0.18 – 4.42) of 3.15° (Figure 3.5).

*Beach flora*

Spinifex (*Spinifex sericeus*), Beach Morning Glory (*Ipomoea brasiliensis*), Coastal Pigface (*Carpobrotus glaucescens)*, Sesuvium (*Sesuvium portulacastrum*), Coastal Wattle (*Acacia sophorae*), Bitou (*Chrysanthemoides monilifera*), Yellow Wood Sorrel (*Oxalis rubens*), Onion Weed (*Trachyandra divaricate*) and American Pennywort (*Hydrocotyle bonariensis*) occurred on the dunes within the study area.

**Table 3.4**: Generalised linear regression results for physical characteristics of beaches as explanatory factors for the presence of Australian Pied Oystercatchers.

| *Model Parameters* | AIC | $AIC_c$ | $\Delta AIC_c$ | *Akaike weight* |
|---|---|---|---|---|
| Slope, beach length, isolation | 30.193 | 33.621 | **0.000** | **0.742** |
| Slope, beach length, fore-dune width, isolation | 29.805 | 36.471 | 2.850 | 0.179 |
| Slope, beach length, sediment type 1, isolation | 31.701 | 38.368 | 4.747 | 0.069 |
| Slope, beach length, fore-dune width, sediment type 1, isolation | 30.240 | 42.240 | 8.619 | 0.010 |
| Slope, beach length, fore-dune width, sediment type 1, sediment type 2, isolation | 31.510 | 52.510 | 18.889 | 0.000 |
| Slope, beach length, fore-dune width, sediment type 1, sediment type 2, isolation, dune height | 33.14 | 70.473 | 36.852 | 0.000 |
| Slope, beach width, beach length, fore-dune width, sediment type 1, sediment type 2, isolation, dune height | 34.778 | 106.778 | 73.157 | 0.000 |

Note: The response variable for all models tested is oystercatcher presence/absence. Sample size (number of beaches assessed) = 11.

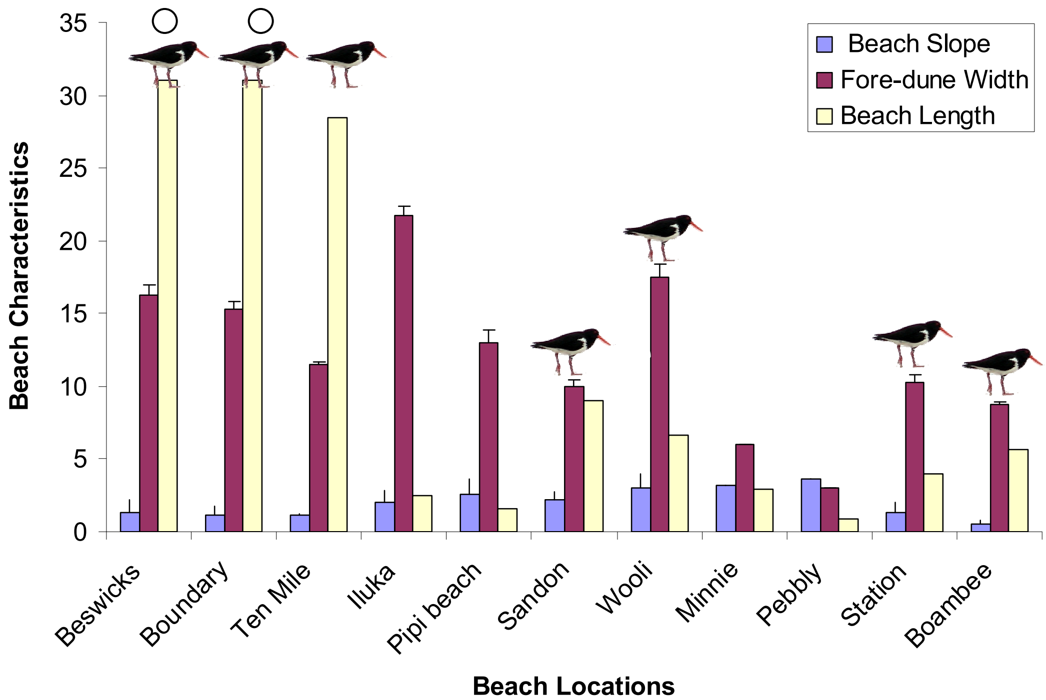


**Figure 3.5**: Mean beach slope and fore-dune width and beach length (consistent beach lengths, thus no SE bars) of all beach sites surveyed. Beswicks and Boundary are both beaches making up the South Ballina Beach location. Oystercatchers indicate presence at least once during counts, ○ indicates beaches where nesting occurred.

Model analysis indicated that two candidate models have substantial support as the best predictor model for oystercatcher presence (Table 3.5). Sand and Bitou occur in all models with $\Delta AIC_c$ of <10, and these alone provided the greatest weight of evidence ($w_i = 0.435$), suggesting that they constitute the best predictors of presence (Table 3.5). However, the inclusion of fore-dune Spinifex also provides a good weight of evidence. Hence, Australian Pied Oystercatchers appear more likely to occur on beaches where Bitou occurs on the dunes (optimum coverage between 5-20%) but where dunes remain open allowing bare sand to dominate (40-50% cover).

**Table 3.5**: Generalised linear regression model results for beach dune flora as predictors of presence or absence of Australian Pied Oystercatchers. The response variable for all models tested is oystercatcher presence/absence. Sample size (number of beaches assessed) = 11.

| *Model Parameters* | AIC | AICc | *$\Delta AIC_c$* | *Akaike weight* |
|---|---|---|---|---|
| Bitou, sand | 60.415 | 61.915 | **0.000** | **0.435** |
| Bitou, sand, fore-dune spinifex | 59.084 | 62.513 | **0.598** | **0.323** |
| Bitou, sand, pigface | 60.555 | 63.983 | 2.068 | 0.155 |
| Pigface, bitou, sand, fore-dune spinifex | 59.496 | 66.162 | 4.247 | 0.052 |
| Wattle, bitou, sand, fore-dune spinifex | 60.522 | 67.189 | 5.274 | 0.031 |
| Pigface, wattle, bitou, sand, fore-dune spinifex | 60.163 | 72.163 | 10.248 | 0.003 |
| Spinifex, wattle, bitou, sand, fore-dune spinifex | 62.305 | 74.305 | 12.390 | 0.001 |
| Spinifex, sand, bitou, fore-dune spinifex | 60.978 | 76.645 | 14.730 | 0.000 |
| Pigface, wattle, pennywort, bitou, sand, fore-dune spinifex | 61.25 | 82.25 | 20.335 | 0.000 |
| Morning glory, pigface, wattle, pennywort, bitou, sand, fore-dune spinifex | 62.74 | 100.073 | 38.158 | 0.000 |
| Spinifex, morning glory, pigface, wattle, pennywort, bitou, sand, fore-dune spinifex | 64.11 | 136.11 | 74.195 | 0.000 |
| Spinifex, morning glory, pigface, wattle, pennywort, bitou, sand, wood sorrel, fore-dune spinifex | 65.94 | 245.94 | 184.025 | 0.000 |
| Spinifex, morning glory, pigface, wattle, pennywort, bitou, sand, wood sorrel, onion weed, fore-dune spinifex | 65.937 | - | - | - |

*Estuary physical characteristics*

All sites with a catchment area >100 $km^2$ contained oystercatchers. These estuaries also contained mangrove growth covering an area > 0.2 $km^2$, had a river length of > 20 km and were permanently open bodies of water, i.e. open entrances. Estuaries holding at least one nesting pair had an average catchment area of 40 $km^2$ while those without nesting birds had an average area of 20 $km^2$ (Table 3.6). Model analysis indicated that the most important factors determining presence of oystercatchers within estuaries were catchment area and river length as all models with $\Delta AIC_c$ <10 had these variables (Table 3.7).

However, where catchment area was < 50 $km^2$ it was less clear what physical factors determined presence. This is likely due to low sample size and lack of historic and current use included in analysis. However, six of the eight sites with birds contained mangrove, seagrass and saltmarsh areas, thus areas of intertidal mudflats. The majority of estuaries without nesting birds (four out of the five) were ICOLs (Intermittently Closed and Open Lagoons/Lakes). Three of these, Woolgoolga Lake/Estuary, Darkum Creek/Estuary and Hearns Lake/Estuary also have a history of pollution from pesticide and sewage runoff but also lack a wide area of intertidal flats. The fourth, Arrawarra Creek/Estuary is also skirted by a caravan park and endures moderate tourism. Such lagoons are particularly sensitive to pollution in their closed states (DIPNR 2004). The only open entrance estuary not occupied, Boambee Estuary, is influenced by a high level of seasonal disturbance from tourists.

**Table 3.6**: Physical characteristics of all estuaries within northern NSW that fall within the current study area, of these 13 sites, eight are used as breeding sites by Australian Pied Oystercatchers.

| | Breeding pairs (Number) | Catchment area ($km^2$) | Waterway area ($km^2$) | Mangrove Area ($km^2$) | Seagrass Area ($km^2$) | Saltmarsh Area ($km^2$) | Entrance | River length (km) |
|---|---|---|---|---|---|---|---|---|
| Clarence Estuary | 3 | 22400 | 89 | 5.208 | 19.072 | 1.954 | Open | 250 |
| Wooli Wooli River | 3 | 190 | 1.9 | 0.493 | 0.028 | 0.531 | Open | 20 |
| Corindi River | 3 | 148 | 0.6 | 0.189 | 0.033 | 0.293 | Open | 25 |
| Bonville Estuary | 2 | 110 | 1.5 | 0.053 | 0.008 | 0.148 | Open | 15 |
| Sandon River | 1 | 109 | 1.5 | 0.533 | 0.028 | 0.258 | Open | 15 |
| Moonee Estuary | 1 | 40 | 0.3 | 0.036 | 0.004 | 0.073 | Open | 13 |
| Lake Cakora | 1 | 11 | 0.3 | 0 | 0 | 0 | ICOL | 5 |
| Station Creek | 1 | 0 | 0.23 | 0 | 0 | 0 | ICOL | 3 |
| Boambee Estuary | 0 | 45 | 0.57 | 0 | 0.036 | 0 | Open | 10 |
| Woolgoolga Lake | 0 | 25 | 0.3 | 0.002 | 0 | 0 | ICOL | 5 |
| Arrawarra | 0 | 20 | 0.2 | 0 | 0.003 | 0.008 | ICOL | 5 |
| Hearns Lake | 0 | 9 | 0.3 | 0.044 | 0 | 0 | ICOL | 2 |
| Darkum | 0 | 0 | 0.046 | 0.001 | 0 | 0 | ICOL | 2 |

Note: Physical data taken from DLWC (1999); ICOL = Intermittent Closed and Open Lake/lagoon.

**Table 3.7**: Generalised linear regression model results for physical characteristics of estuaries within northern NSW as predictors of presence or absence of Australian Pied Oystercatchers. The response variable for all models tested is oystercatcher presence/absence. Sample size (number of estuaries assessed) = 13.

| *Model parameters* | AIC | AICc | *$\Delta AIC_c$* | *Akaike weight* |
|---|---|---|---|---|
| Catchment area, river length | 19.529 | 20.729 | **0.000** | **0.516** |
| Catchment area, waterway area, river length | 20.724 | 23.391 | 2.662 | 0.136 |
| Catchment area*, river length, mangrove area | 21.225 | 23.892 | 3.163 | 0.106 |
| Catchment area, river length, seagrass area | 21.285 | 23.952 | 3.223 | 0.103 |
| Catchment area, river length, entrance characteristics | 21.492 | 24.159 | 3.430 | 0.093 |
| Catchment area, waterway area, entrance characteristics, river length | 22.299 | 27.299 | 6.57 | 0.019 |
| Catchment area, river length, entrance characteristics, mangrove area | 23.174 | 28.174 | 7.445 | 0.012 |
| Catchment area, river length, entrance characteristics, seagrass area | 23.253 | 28.253 | 7.524 | 0.012 |
| Catchment area, waterway area, seagrass area, entrance characteristics, river length | 23.19 | 31.76 | 11.031 | 0.002 |
| Catchment area, waterway area, mangrove area, seagrass area, entrance characteristics, river length | 25.04 | 39.04 | 18.311 | 0.000 |
| Catchment area, waterway area, mangrove area, seagrass area, salt-grass area, entrance characteristics, river length | 26.53 | 48.93 | 28.201 | 0.000 |

## 3.5 Discussion

### *3.5.1 Australian Pied Oystercatcher population and trends*

Previously, Australian Pied Oystercatcher numbers from Coffs Harbour to the Richmond River were estimated at 72 individuals (Smith 1991) on the basis of compiled counts from various parts of the coast over 20 years (1970-1990). During the mid 1990s, 70 individuals were again estimated for this region (Chafer 1995). However, during the mid and late 1990s, two co-ordinated counts, from the Richmond River through to the Clarence River provided estimates of 79 and 99 individuals respectively, including flocks of up to 40 non-breeders on Ten Mile Beach (R. Moffatt in Burton and Morris 1993, R. Moffatt in Gosper and Holmes 2002). This indicates an increase in numbers, despite no count being made south of the Clarence River. Further thorough counts during 1996, 1998 and 2000 were organised by the

Australasian Wader Study Group (AWSG), with each section of NSW coast covered concurrently by volunteers. These counts gave estimates of 161, 202 and 185 individuals (AWSG unpublished data, Figure 3.6) for the north coast region (current study area) in those years. We suggest that the latter more rigorous counts, conducted by Moffatt and AWSG are likely most accurate. Although it appears that the Australian Pied Oystercatcher population increased during the 1990s, this was likely to be to a lesser degree than suggested (Figure 3.6), given the methods used to determine those earlier estimates. However, the sharp decline subsequent to the 1990s is based on rigorous counts and should be cause for concern. This decline continued through 2003 and 2005, with a net loss of 13.2% between these later years. In agreement with previous studies in Victoria and north-western Australia, we found that around 30% of the population consisted of non-breeding birds, at least in 2003 (Weston 1993, Minton 1997, Kraaijeveld-Smit *et al.* 2004). Recent counts confirm that the northern region represents a stronghold for the species (Owner and Rohweder 2003), with the state population estimated at only 250 birds (Watkins 1993). However such low numbers in this region and the continuing decline highlight the vulnerable state of the species.

The recent decline identified in all cohorts between 2003 and 2005, was most evident for floater birds (-33%), followed by breeding pairs (-17.1%) and then by non-breeding territory holders (-4.7%). This suggests that territory holders are being lost and only partly replaced by floaters, but that the number of birds available to potentially become breeders is also declining. Such declines may indicate that many territories may now be held by younger individuals (as represented by the notable loss of immature birds). A small proportion of consistent territory holders did not breed in any year, as found for *H. chathamensis* (Schmechel 2001), which may be related to old age (Dhondt 1985). Similarly, the decrease in birds actually breeding may also suggest that less experienced birds are occupying territories but may be immature and may therefore forego breeding (du Plessis *et al.* 1995, Arnold and Owens 1998). If this is the case, then it suggests that older birds are dying at a high rate, or that territory quality has declined, as local dominance structure generally does not allow less experienced birds to occupy premium territories (Ens *et al.* 1992, Heg *et al.* 2003). Although we suggest 10% annual adult mortality as estimated by others (Newman 1984, 1989), we suspect, as recently found for *H. ostralegus* (le V. dit Durell 2007) that this is an underestimate. We suspect higher mortality owing partly to disturbance such as vehicle traffic in the north of this region (Harrison 2005), and at least some birds in the south appear quite old. Furthermore, harsh conditions have been experienced over the past decade, with the most severe drought in the last century (Bond *et al.* 2008). Such conditions may result in reduced food supply (Ruello 1973, Peterson and Jennings 2007), thus have implications for fitness and survivorship.

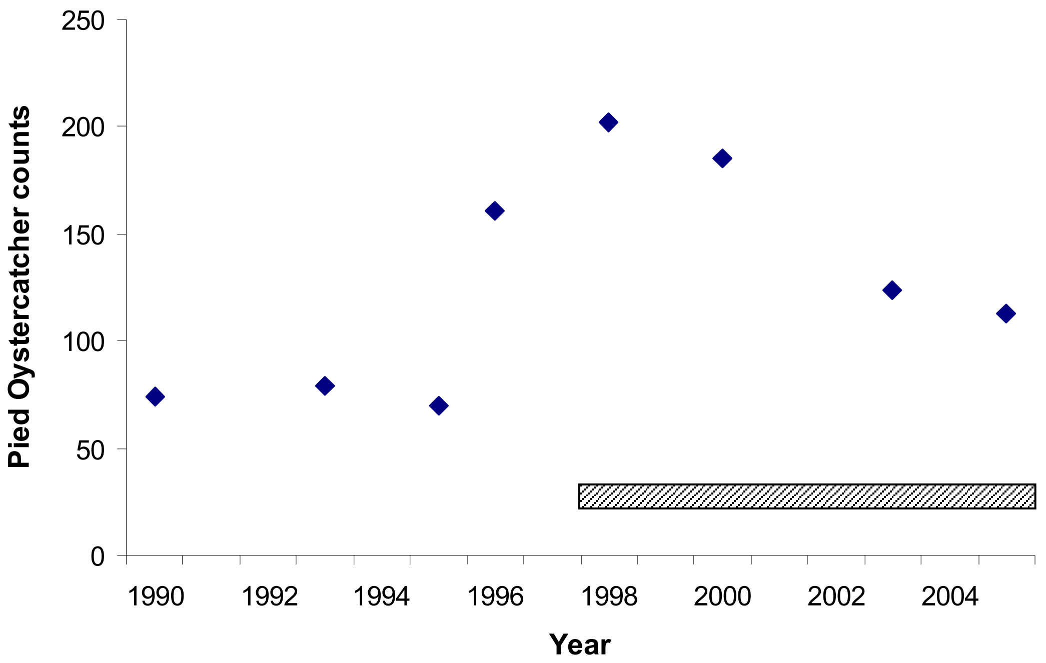


**Figure 3.6**: Australian Pied Oystercatcher counts in northern NSW Australia between 1990 and 2005. Note: 1990 data source = Smith (1991); 1993 data source = R. Moffatt in Burton and Morris (1993) and R. Moffatt in Gosper and Holmes (2002); 1995 data source = Chafer (1995); 1996, 1998 and 2000 data source = Unpublished AWSG data; 2003 and 2005 data source = Harrison, this work. ▨ Indicates period of fox baiting.

### *3.5.2 Influence of beach morphology and prey density*

Habitat use by shorebirds has previously been suggested to be driven by factors including prey density and quality and the factors that drive these (Goss-Custard *et al.* 1977, Evans and Dugan 1984, Hulscher 1996), presence of estuaries, beach characteristics, predator abundance (Owner and Rohweder 2003) and presence of humans (Lindberg *et al.* 1998, Leseberg *et al.* 2000, Liley and Sutherland 2007). Here I also find that Australian Pied Oystercatcher distribution is related to a number of factors, principally food availability (pipi, soldier crab and polychaete), which may be related to a number of factors including weather conditions and external drivers, but also habitat characteristics such as beach morphology, vegetative cover of dunes, estuary catchment size and the level of disturbance at sites.

Beach morphology, (length, slope, sand particle size) and wave action determine diversity and abundance of invertebrate fauna. As beaches become more dissipative, gently sloping with fine sand particles, diversity increases (Jones and Short 1995, Short 2000, Hacking 2007). Accordingly, presence of oystercatchers is determined by prey availability, and hence, is also related to beach morphology, as earlier suggested by others (Owner and Rohweder 2003). Consequently, in the north of the region, where beaches are long and gently sloping, they accommodate a high density of large pipis and a higher density of Australian Pied Oystercatchers.

Moving south of the Clarence River, beaches become shorter and steeper and the number and size of pipis reduces. However, the number of estuaries, containing a large diversity and abundance of prey increases. Consequently, highly abundant prey such as soldier crabs and polychaetes become more profitable (A. Harrison unpublished data, Ens *et al.* 1996, Zwarts *et al.* 1996, Norris and Johnstone 1998) and oystercatchers are therefore more likely to forage and nest in estuarine habitat. The patchy and unpredictable nature of beach invertebrates may also explain why others have previously indicated that Australian Pied Oystercatchers place nests on sandy beaches where intertidal feeding grounds were also available (Lauro and Nol 1995b, Owner and Rohweder 2003), as these may provide a more reliable source of food, and offer greater protection to birds and their chicks. However, as flow rates, level of pollution, range of micro-habitats and catchment size are also linked with prey diversity and abundance (Hastie and Smith 2006), only those that provide high densities of key prey species shall be occupied. Similarly, smaller closed estuaries (ICOLs) lacking in intertidal flats, are unlikely to maintain oystercatchers.

### *3.5.3 Influence of dune flora*

Australian Pied and other Oystercatchers have previously been shown to prefer high visibility nesting sites on open beaches (Newman and Park 1993, Lauro and Nol 1995a, Watson *et al.* 1997). While I concur, finding that bare sand is an important predictor of nesting sites, here I also find a significant association with the presence of Bitou Bush on dunes, i.e. backing nests. Although densities of Bitou were not high (5-20%), it is evident that some structure or cover is preferred. The preference for cover close to nests is also exhibited by estuary nesting birds (thesis chapter four). With increasing threats, Bitou, located above the high water mark, provides cover and protection for chicks, particularly during high tide periods, when habitat is extremely limited and risk to potential threats is greatest. However, the relationship may simply be because structure is preferred on dunes to act against prevailing wind and erosion at beach nest sites, and provide shade (Lauro and Nol 1993).

### *3.5.4 Influence of disturbance*

There are numerous stretches of coast unoccupied by breeding pairs. Nesting density within the region is lower than elsewhere in Australia. Even at the site of highest abundance (17 nesting pairs in 2005) South Ballina, density still only approximates the lowest densities recorded in other states such as Tasmania and Victoria (density ranged from 0.5 to 4.7 pairs $km^{-1}$, averaging 2.5 pairs $km^{-1}$ in Victoria, (summarised by Marchant and Higgins 1993). While this may suggest that suitable habitat is not all occupied (Ens *et al.* 1992, Braby and Underhill 2007), modelling indicates that few other beaches are suitable. Although some are suitable in terms of beach length and prey density, e.g. Ten Mile Beach, Wooli Beach and Boambee Estuary, they endure high seasonal disturbance by recreational users. Disturbance is known to deter foraging and breeding birds (Burger 1994, Taylor and Bester 1999, Leseberg *et al.* 2000). Such seasonal disturbance may, in part, explain why such sites are used in the winter for foraging, but no nesting was found. Sandon Estuary currently holds one breeding pair (although a second is suspected G. Clancy pers. comm.) and based on catchment size and prey abundance, it also has the potential to hold another pair. However, this site too has a seasonal impact of recreational users. Thus, while there is potential to increase the number of breeding pairs, this would depend on reducing human disturbance during the breeding season.

At the smaller scale, within beaches of general suitability, human disturbance resulted in avoidance of some beach sections. Reductions in shorebird presence, of 30-50% have been reported elsewhere, due to human presence with reductions most evident when disturbance levels were high (Burger 1981, Pfister *et al.* 1992, Burger 1994, Liley and Sutherland 2007). All three vehicle access points to the beach were subject during the survey period to a similar number of vehicle passes (Ballina Shire Council unpublished data). However, the central point, with the greatest distance (up to 5.5 km) of beach unoccupied by nesting oystercatchers, had frequent pedestrians (and pets), sunbathers, swimmers and other recreational use (also adjacent to a small town). Humans particularly when accompanied by dogs are a proven disturbance to shorebirds, and are known to cause increased response by birds (Yalden and Yalden 1990, Lafferty 2001, Miller *et al.* 2001). The northern access point, similarly unoccupied by oystercatchers, also has frequent recreational use and occasional dog use (and is adjacent to a holiday park). The southern access point, with the shortest stretch of unoccupied beach, has a lack of frequent or intense foot traffic by recreational users or pets (no caravan park, car park or homes directly behind dune and with a longer walk from any road) and birds nest closer to that vehicle access point, although still at least 700 m away at a minimum. Thus, the combination of frequent dog attendance, frequent recreation and vehicle use appears here to prevent Australian Pied Oystercatchers from using those areas to a greater degree than vehicles alone. All disturbances however, have been shown to deter birds from using those areas.

### *3.5.5 Experience of birds*

Where pairs occurred adjacent to access points on South Ballina Beach many contained banded individuals (four to seven years old), and in one case a single male that did not acquire a mate all season, thus reflecting the 'poorer quality' of such sites. Due to the strong site fidelity and territorial behaviour of experienced breeding birds (Marchant and Higgins 1993), young birds, as earlier indicated, may not be in a position to acquire premium territories, thus may be restricted to take up less suitable areas (Heg *et al.* 2003). Such birds may also subsequently suffer breeding failure due to inexperience, and to disturbance (Harris 1969, Rusticali *et al.* 1999, Heg and van der Velde 2001, Penteriani *et al.* 2003, Murison *et al.* 2007). The presence of such birds in this population further suggests that experienced birds have been lost and may indicate that turnover rate of occupied territories near access points is high. With ever increasing pressure for coastal development, access to coastal resources and recreation, territories even further from access points may also be abandoned by experienced breeders in the future (Liley and Sutherland 2007).

### *3.5.6 Implications for management*

Although the north coast of New South Wales represents a stronghold for the Australian Pied Oystercatcher within the state, the current population estimate of 112 birds for the region highlights cause for concern, particularly considering the declining trend (decline of 13% between 2003 and 2005). The occupation of suitable sites requires that there are potential breeders to replace dying birds, which currently may not be the case. Continued banding and monitoring of populations over the long-term are essential to a better understanding of the life history of this species. However, in the interim, action is needed to halt this decline.

Oystercatcher populations are dependent on prey densities which are related to habitat structure and health, but also to the over-riding level of human disturbance. Measures to protect prey populations should be of concern to managers. Given that beach morphology and estuary size and health, thus prey abundance, determine oystercatcher presence and have potential to drive populations, management should focus on mitigating threats that impact upon beach morphology and changes to hydrological systems. With the increasing impact of storm damage and erosion as a result of global warming and sea-level rise, managers may need to adopt adaptive management actions that assist species in a changing environment (Jones *et al.* 2004, Chambers *et al.* 2005). Furthermore, activities that reduce the abundance of prey with potential to have an enormous impact upon the species should be ceased. Currently pipis (*D. deltoides*), the main food source for beach birds, are harvested commercially and recreationally in northern NSW. However, little research has taken place on the practice, despite the removal of shellfish elsewhere having a huge impact upon oystercatcher numbers (Lambeck *et al.* 1996, Ens *et al.* 2004, Atkinson *et al.* 2003, 2006)..

The relationship between Bitou, identified as a predictor of good oystercatcher nesting habitat, and other native species such as Coastal Wattle, which should replace Bitou once eradicated, and Australian Pied Oystercatchers may need further investigation. Bitou is listed as a noxious weed (Noxious Weeds Act 1993) and is currently being managed. However, the complete removal of this species may have a negative impact upon Australian Pied Oystercatchers, particularly if the removal reduces reestablishment potential of other plant species, and also if the removal of this species leaves dunes barren until the re-establishment of native species.

Coastal environments and species already face a range of threats. Furthermore changes in the degree or manner of disturbances may have large consequences on long-term survival and sustainability of species. Australian Pied Oystercatchers avoid areas frequently disturbed by recreational users and their pets, furthermore, are subject to increased mortality via vehicle impact (Harrison 2005, see Appendix B). As this species is listed as threatened in NSW, efforts must be made to mitigate threatening processes. Preventing the loss of experienced breeders from this population due to abandonment of traditional sites and increased mortality should be a priority. Thus, minimising access points (particularly at South Ballina Beach) should be sought and human disturbance (recreational and pets) should also be minimised in an effort to increase numbers and survivorship of the species.

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## CHAPTER 4

## Breeding success of beach– and estuary-nesting Australian Pied Oystercatchers (*Haematopus longirostris*) in relationship to predation and food availability

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**Abstract**

The Australian Pied Oystercatcher (*Haematopus longirostris*) is listed as Vulnerable in New South Wales (NSW). Breeding biology and threats to the species were examined at beach and estuarine nest sites in northern NSW during the years 2003 to 2005. Variation occurred in all measures of success over the three breeding seasons and between habitat types. Hatching (46.3%) and fledging (51.0%) success were higher in estuaries than on beaches and overall estuarine pairs produced significantly more fledglings per pair than beach pairs (0.90 c.f. 0.31) as predicted. Beach nests were largely depredated by foxes (*Vulpes vulpes*), whereas estuary nests were largely depredated by Torresian Crows (*Corvus orru*), Lace Monitors (*Varanus varius*) and lost to high tides; many more beach nests were lost. Overall predation (33.9%), tidal flooding/sand cover (6.9%), and human disturbance/abandonment (6.1%) were the major identified causes. Human disturbance occurred in both habitats accounting for egg and adult loss. Domestic dogs and raptors were the only identified source of chick loss. A severe decline in the primary food source (*Donax deltoides*) for beach pairs was evident, coinciding with reduced productivity between years. While fox control is crucial particularly at beach sites, several other factors contributing to the species decline are evident, these are discussed.

**Key words**: reproductive success, fox predation, bivalve fishery, productivity, beach-nesting, estuary-nesting, oystercatchers.

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Chapter 4 available on request

**CHAPTER 5**

The impact of recreational and natural disturbance on the behaviour of incubating Australian Pied Oystercatchers (*Haematopus longirostris*) in sub-tropical New South Wales


## Abstract

With ever-increasing pressure placed on coastal environments by recreational users and developers, the need for understanding the impact of threatening processes upon species and for protecting biodiversity has never been greater. The impact of anthropogenic and natural disturbance on the behaviour of incubating Pied Oystercatchers was investigated in northern New South Wales during the breeding seasons of 2003/04 and 2005/06. Birds were disturbed frequently, which resulted in incubating birds being absent from their nests for 21.5% of survey time. The longest continuous nest absence lasted 1 hr and 24 mins. Non-incubating partners foraging close to nests were also disturbed for 18.4% of time. Human disturbance accounted for 83.1% of time spent off nests. Recreation involving dogs on mid and high beach zones was particularly threatening, as was recreation on dunes, leading to frequent and long absences from the nest. Other recreation including fishing, swimming, walking and picnicking also resulted in significantly longer periods of nest absence than approaches by raptors and vehicles. Observer disturbance resulted in periods of nest absence similar to that resulting from natural stimuli and revealed that estuary birds defend their nests longer than beach birds do. However, beach birds may have been more habituated to disturbance. Management plans for the Australian Pied Oystercatcher in NSW should aim to minimise disturbance to breeding birds, by enforcing a buffer zone around active nests (radius of 194 m minimum) signposted on the dune. These buffers should allow vehicles to pass slowly on the low beach, but be strictly no stopping zones for vehicles and exclude people and their pets. Buffers should remain until chicks fledge, so that nests, vulnerable chicks and parents sharing duties are protected. To ensure long-term protection, access paths to beaches should be limited also to non-breeding areas through provisions in local planning policy. Furthermore, remaining dog exercise areas should be restricted only to non-breeding areas.



**Key words**: Human disturbance, flush distances, set-back distances, vehicle traffic, recreational disturbance, dogs.

## 5.1 Introduction

Shorebirds have become increasingly threatened as a result of predation, competition, sea-level rise, coastal development and recreational activity throughout many parts of their range globally (Priest *et al.* 2002, BirdLife International 2004). Over the past century, increasing numbers of people have sought a permanent change of residence to coastal regions while many also flock to those areas annually for holidays, particularly during spring and summer months. During this period of affluence and greater time available for leisure, a greater desire for water-associated recreation and coastal lifestyles has developed, with increased access to coastal resources made available (Short 2000). In Australia, coastal growth has been exacerbated in the past decade by shifts away from inland regions by those severely affected by drought (Australian Bureau of Statistics 2008). With increasing numbers of residents and recreationalists predicted, along with rising sea levels and associated loss of habitat, the frequency of interactions between shorebirds and humans is set to intensify in this already limited habitat (Short 2000, Chambers *et al.* 2005).

Bird species richness and abundance has been shown to be negatively impacted by human disturbance, with waders identified as the most sensitive group of species (Burger 1981, Cardoni *et al.* 2008). Several studies have indicated that the frequent presence of humans disrupts habitat use, foraging activity, breeding activity and success of shorebirds (Hockin *et al.* 1992, Burger 1994, Lord *et al.* 1997, Verhulst *et al.* 2001, Langston *et al.* 2007), to the point that shorelines frequented by humans typically lack some of these species (Burger 1981, Lindberg *et al.* 1998). The pressure of anthropogenic disturbance is particularly high for species that rely entirely upon the narrow coastal strip for their survival, such as permanent beach residents, and also those that are restricted to limited territories during breeding months that coincide or overlap with peak holiday periods.

In Australia both migratory and resident shorebird species are at risk from disturbance and other threatening processes, with many listed as endangered and vulnerable or facing decline nationally or in certain states (Garnett and Crowley 2000, DECC 2008). One species of concern, listed as a *Vulnerable Species* in on Schedule II of the New South Wales Threatened Species Conservation Act (1995) is the Australian Pied Oystercatcher (*Haematopus longirostris*). With only 250-480 individuals reported for the state (Smith 1991, Watkins 1993), and declines continuing (thesis Chapter 3), the species is currently being considered for upgrade to Endangered (S. Debus pers. comm.). These resident shorebirds are restricted to the narrow shorelines of tropical and temperate Australia. Ocean beaches, sand-spits and sand islands within estuaries are used for breeding and feeding. Foraging habitat on most beaches is as little as 200 m wide during low tide and less than 15 m wide at high tide.

Nesting coincides with peak recreational periods, i.e. spring and summer holiday months September-October and December-January. Consequently, birds are forced to compete for space in narrow and limited habitat during vulnerable periods. Nests are generally mere scrapes in the sand placed above the high water mark on the fore-dune (sparsely vegetated area above high water mark) or first proper dune in beach habitat, or on fringing habitat surrounding estuaries. The lack of an elaborate nest along with the camouflaged eggs means that eggs (and nests) blend in with surrounding sand, pebbles, debris and surrounding vegetation (Lane 1987, Lauro and Nol 1993, Marchant and Higgins 1993). Consequently, ground-nests are often very accessible to humans, yet are easily overlooked by recreational users and therefore very susceptible to trampling and other disturbance (Smith 1991, Priest *et al.* 2002, Pearce-Higgins *et al.* 2007).

Inadvertent disturbance, such as walking, picnicking, swimming, driving and fishing, may disturb birds and result in birds being forced off nests temporarily, leaving eggs exposed to the elements (over-heating or cooling) and to predation by feral and domestic animals (Dowling and Weston 1999, Ruhlen *et al.* 2003). Responses of birds to such inadvertent disturbance may involve avoidance behaviour such as walking or flying, and the cessation of parental care such as incubation and guarding of chicks, foraging or resting behaviour. Over time continued disturbance, resulting in increased defensive behaviour, may result in energetic costs via increased flight, reduced foraging time and increased stress levels (Yalden and Yalden 1990, Burger and Gochfled 1991, Hockin *et al.* 1992, Burger 1994, Lafferty 2001, Taylor and Knight 2003). These costs may then impact upon reproductive capacity, growth and survival of individuals and populations (Geist 1978, Burger 1994, Watson and Kerley 1995, Verhulst *et al.* 2001, West *et al.* 2002, Ruhlen *et al.* 2003, Müllner *et al.* 2004, Murison *et al.* 2007, Stillman *et al.* 2007). Exacerbating the impact upon resident breeding shorebirds are the behavioural aspects of some species; defending narrow beach territories where little option for alternative foraging grounds is available. Therefore, compensating for time lost incubating is often difficult (Leseberg *et al.* 2000).

Other threats to the Australian Pied Oystercatcher (APOC) include: predation of eggs, chicks and adults by foxes, feral and domestic dogs and cats; predation of eggs and chicks by goannas, crabs and avian predators; habitat loss through both natural and human induced processes; pollution of estuaries and coastal areas; tidal flooding of nests; and wind blown sand covering nests (Lane 1987, Buick and Paton 1989, Newman 1991, Priest *et al.* 2002, Lauro and Nol 1993, Marchant and Higgins 1993, Lauro and Nol 1993, Watkins 1993).

As coastal habitation continues to grow, managers are increasingly forced to make decisions about the types of use and access allowed to areas, keeping in mind public use values, while also trying to conserve wildlife. Information on the impacts of various types of threats including recreational activities is required to make such decisions (Yalden and Yalden 1988, Taylor and Knight 2003, Weston 2007).

The objective of this work was to determine whether disturbance constitutes a management issue in northern NSW, and if so, which recreational activities (or stimuli) impact upon the behaviour of the APOC during incubation, and which activities were most disturbing. Furthermore, to determine set-back or buffer distances at which disturbance would be minimised. As an indicator of the relative impact of disturbance, natural stimuli were also considered. Observer disturbance (while checking nests for data produced in Chapter 4) has also been examined with regard to difference in responses between habitat types.

## 5.2 Study area

Disturbance to incubating birds was monitored at locations from the Bonville Estuary at Sawtell (30$^{o}$16'S, 153$^{o}$05'E) to South Ballina Beach (Richmond River, 28$^{o}$50'S, 153$^{o}$31'E, Figure 5.1) in northern NSW, which are described in detail in Chapter 3.

## 5.3 Methods

### *5.3.1 Field surveys*

Surveys were conducted throughout the breeding seasons of 2003 and 2005. Forty-one pairs of APOCs inhabited this region, 23 of which were observed while incubating during this period (Figure 5.1). Responses of incubating birds, at both beach and estuary nests, to observer disturbance was recorded, i.e. in the course of checking nest contents (see Chapter 3). Nests were approached steadily and quietly on foot and time spent at nests was consistently less than one minute. The following details were documented: response distance, i.e. distance at which the bird left the nest in response to approaching observer (paced out in metres on approach to the nest); response of birds (walk, fly, run); flush distance (distance birds moved away from the nest, visually estimated against placed markers); response period (total duration of absence from the nest, recorded in minutes); and return distances (distance of observer from the nest when leaving (paced in meters) at which the bird returned and continued to incubate).

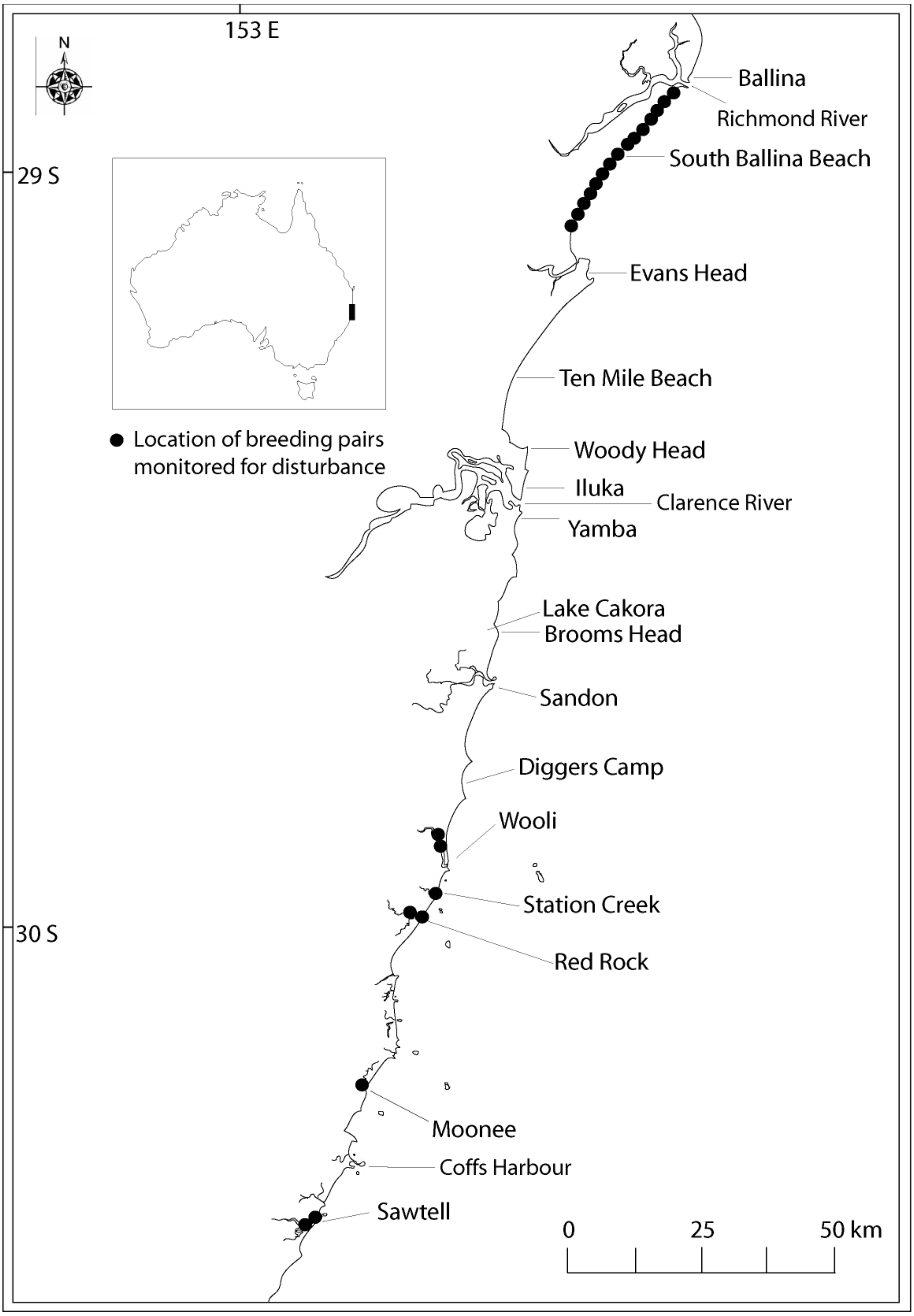


**Figure 5.1**: Location of incubating Australian Pied Oystercatchers monitoring for disturbance (estuary pairs n=8, beach pairs n=15).

Focal animal surveys (Altmann 1974) were also conducted for one hour periods, to monitor responses of incubating birds to human and natural disturbance (Weston 2000, Weston and Elgar 2005). A total of 176 monitoring hours was undertaken on 23 pairs of incubating APOCs. These observations were conducted from a minimum of 200 m from the nest (or as determined to be non-disturbing), from within a vehicle at beach nest sites, and from a hidden position at estuary sites. If birds were disturbed by the approach and stop of the survey vehicle, or from the approach to a hide, a habituation period of five minutes was allowed before commencing observations. During surveys the observer remained stationary. All potential disturbance/stimuli were recorded during this time and responses to each documented. Four main stimulus categories included: human, human with pet, vehicle traffic, and natural stimuli. Sub-categories within the human category included: recreation on dune to foredune zone, recreation on mid to high beach zone (moist to dry sand), walking on low beach zone (wet sand), and roaming activity (such as swimming and fishing). Beach zonation is illustrated in Figure 5.2. Vehicle sub-categories included: passing and parking. Sub-categories of humans with pets included: low beach and mid to high beach activity. Natural disturbance sub-categories included: intruding APOCs, eagles, kites, crows, gulls, magpie, other birds (passerines), and migrants[2]. Response categories included nil (birds remained on the nest but may have been alert), standing (birds stood over the nest but did not leave), or absence/departure (birds left the nest).

Data were also collected on the time away from the nest (in minutes) and response distances (distance at which the bird left the nest in response to approaching threat, estimated using previously measured markers). During surveys, incubation periods of males and females attending the nest were also documented, along with periods of absence during the changeover of incubator, which may have also coincided with departure to feed. Sexes were determined based on noticeable difference in bill length in the field (Kraajijeveld-Smit *et al.* 2001). Note that this method was applied on a pair-by-pair basis (i.e. comparison of the two members of a pair), comparison of individuals between pairs was not undertaken as this was often unreliable - some pairs contained individuals with longer bills, whereas others containied individuals with shorter bills; although between the individuals of the pair the sexes were evident. If birds were not incubating upon observer arrival due to disturbances,

[2] Migrants in this context include migratory shorebird species encountered during Pied Oystercatcher disturbance surveys; species included Bar-tailed Godwit (*Limosa lapponica*) and Whimbrel (*Numenius phaeopus*).

and where active nests were present observations were commenced in the absence of an incubating adult.

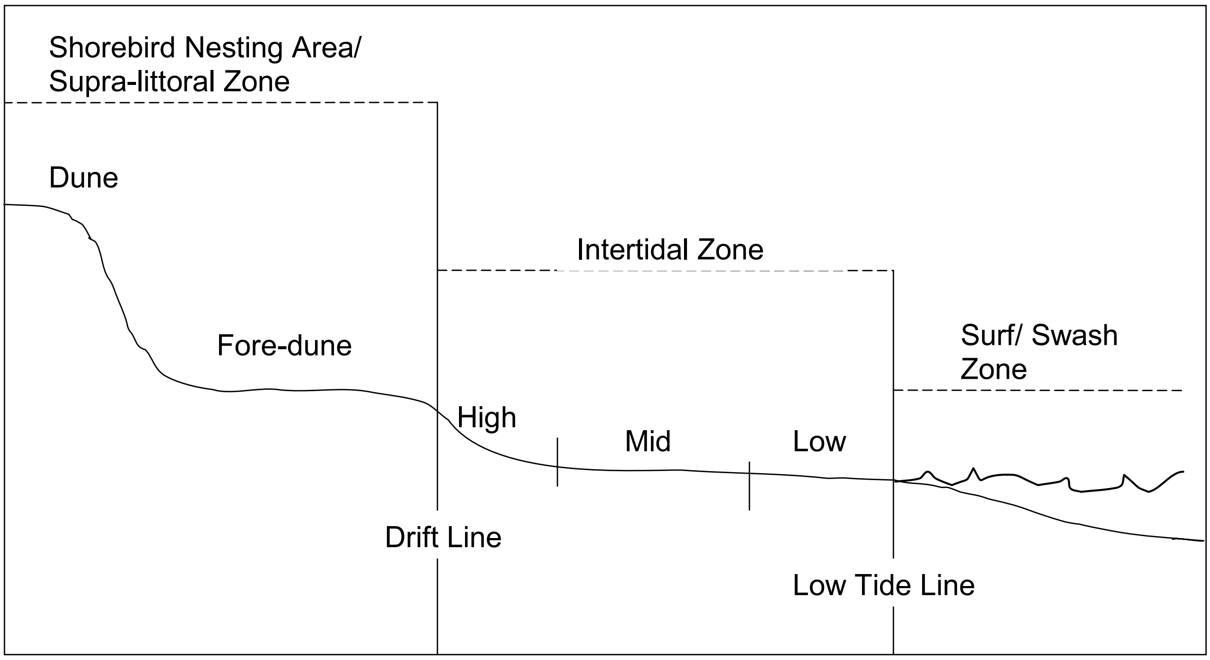


**Figure 5.2:** Sandy beach profile identifying major features including dune and foredune areas (supra-littoral zone) generally used by shorebirds for nesting, intertidal zone and surf/swash zones (where waves meet the shore). Within the intertidal zone, the beach can been further divided to include high, mid and low beach zones (ranging from entirely dry to entirely wet sand).

*5.3.2 Statistical analysis*

Observer disturbance was examined separately for beach and estuary breeding pairs, to determine whether the consistent method of approach resulted in consistent flush distances and durations of nest absence (using analysis of variance) by birds in the different habitat types. Frequency of reactions was also examined between the two habitat types using chi-squared analysis.

To determine whether birds reacted differentially to the various stimulus categories, observed and expected frequencies of nest absences in response to each were compared using chi-squared analysis (Zar 1999). Analysis of variance (ANOVA) was also undertaken using general linear models (GLM) and multiple post-hoc comparisons were made to determine whether different stimuli resulted in different periods of nest absence. Data were first log-transformed to meet test assumptions (Zar 1999, Grafen and Hails 2006). Multiple pair-wise comparisons were performed using Tukey Tests, with a set confidence interval of 95%.

Distances at which birds left the nest in response to humans and humans with pets were also compared using one-way ANOVA. Significant results were indicated in each case by a p-value of $\leq 0.05$.

The desired set-back or buffer distances were calculated using the mean and the standard deviation of the sampled population as per Rodgers and Smith (1995, 1997). The set-back distance is the upper limit of an approximate 95% one-sided confidence interval of the mean. Similar methods have been applied by Stalmaster and Newman (1978), McGarigal *et al.* (1991) and Swarthout and Steidl (2001).

Means are presented with ± 1 SE. Each encounter with a disturbance has been treated as an independent data point within each hour. Therefore data have been excluded where a single event could not be clearly identified as the cause of an absence. However, most could be determined or inferred. Disturbance rates were measured as the number of encounters per hour, regardless of whether an absence occurred. Similarly, the overall disturbance period is a measure of average duration of nest absence per hour.

## 5.4 Results

### *5.4.1 Reactions to observer created disturbance*

Birds were flushed from their nests in response to observer approach for an average of 3.73 (± 0.41) minutes for beach nesting birds [n=30] and 5.40 (± 0.74) minutes for estuary nesting birds [n=15], averaging 4.28 (± 0.38) minutes; estuary nesting birds spent significantly greater periods off the nest that estuary birds during such responses ($F_{[1,43]} = 4.047$, $p = 0.05$).

Incubating birds departed or flushed from the nest upon an observer approaching at distances ranging from 15 to 150 m from the nest. Average flush distance for all birds was 57.25 m. Birds nesting on beaches flushed at an average approach distance of 45.80 (± 4.21) m, whereas estuary nesters flushed at an average 80.10 (± 12.37) m (Figure 5.3). Distances were significantly different between habitat types, with estuary birds leaving the nest at greater distances ($F_{[1,43]} = 10.577$, $p = 0.002$).

Birds returned to their nests when the observer had moved an average of 116.6 m (ranging 35 – 500 m) away from the nest, with an average of 90.0 m (± 7.45) for birds incubating in beach habitat, and 169.8 m (± 28.50) for birds incubating in estuarine habitat (Figure 5.3). Thus, the distance of an observer from the nest at which birds return is also significantly greater ($F_{[1,43]}$ = 12.505, p <0.001) for estuary birds. Beach nesting birds responded to observer disturbance about equally by flying, running or walking away from the nest. Estuary nesters mostly responded by walking (80% of reactions) (Figure 5.4). They also ran from the nest but few flew. Overall, observed frequencies of reactions differed significantly from expected frequencies ($X^2$ =9.049, DF = 2, p = 0.011).

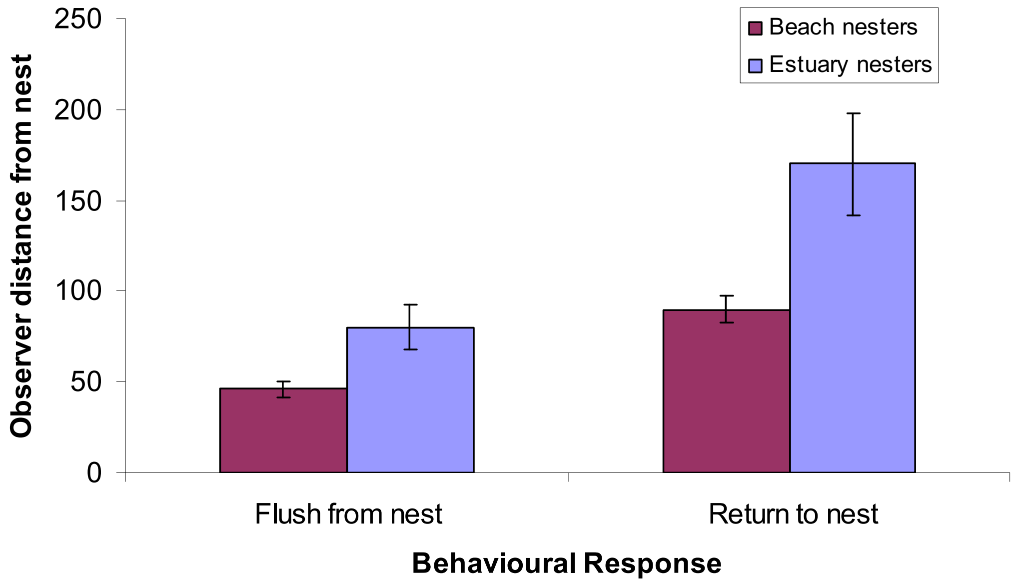


**Figure 5.3**: Mean distance (and standard error) of observer, at which birds left the nest, i.e. flushed, and then returned to nests.

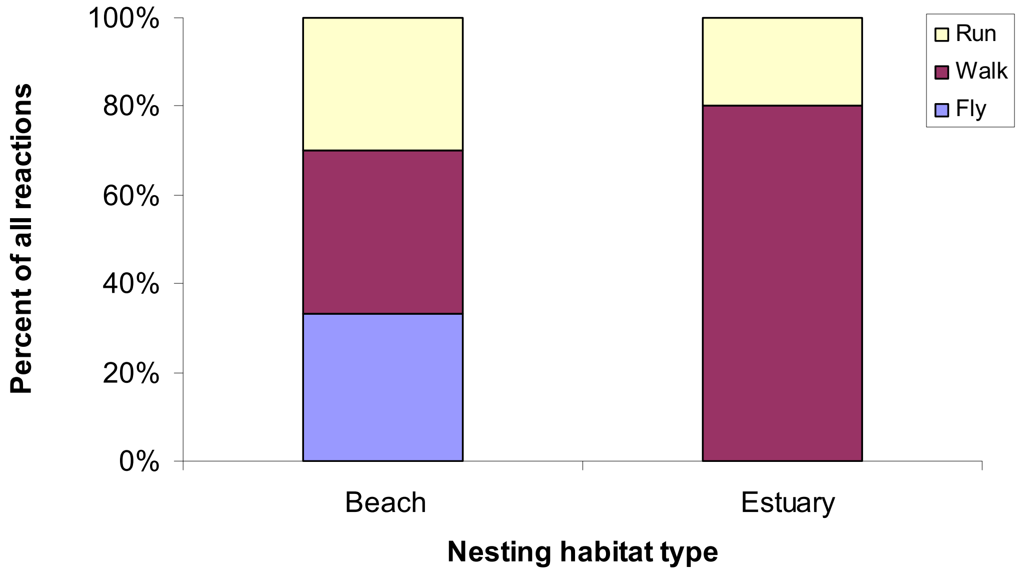


**Figure 5.4**: Reactions given by oystercatchers departing from nests in response to observer approach.

### *5.4.2 Sources of disturbance*

Incubating birds encountered potentially disturbing stimuli at a mean frequency of 3.65 times (± 0.20) $hr^{-1}$ averaging 3.18 (± 0.47) times $hr^{-1}$ in estuary habitat, and 3.75 (± 0.23) times $hr^{-1}$ in beach habitat (n = 176 observation hours). The number of encounters was, however, not significantly different between habitat types ($F_{[1,175]} = 1.05$, $p = 0.308$).

Of all encounters recorded, 57.6% were with human stimuli while 42.5% were with natural stimuli (n = 527 encounters). However, there was variation in the percentages between beach and estuarine habitat (Table 5.1). Human disturbance was largely attributed to recreational/walking activities (66.7%) and vehicle traffic (33.3%). Of human recreational encounters, 28.1% also involved dogs (Table 5.1). Vehicle traffic, including motor cycles and horse riding, was largely limited to beach habitat. Birds were the source of most natural encounters observed. Species most commonly encountered include intruding Australian Pied Oystercatchers, White-bellied Sea Eagle, Brahminy Kite, Whistling Kite, Black-shouldered Kite, Nankeen Kestrel and Osprey, which together accounted for 31.1% of all encounters (Table 5.1). A Lace Monitor (*Varanus varius*) was also observed to disturb incubation and consume eggs. However, nest absence period was not recorded owing to the loss of the clutch. Incidentally, one adult partner belonging to the watched nest had been depredated in prior hours, thus was not able to assist in nest defence. Tracks surrounding the fresh carcass suggested fox (*Vulpes vulpes*) predation.

### *5.4.3 Response to anthropogenic and natural disturbance*

Responses of incubating APOCs included vigilance, crouching, standing over the nest or leaving the nest. Once flushed (absent from the nest), birds later returned to continue incubating, unless eggs had been consumed. Of all encounters, 51.0% resulted in departure, i.e. nest absence (rate of 1.39 ± 0.25 $hr^{-1}$ in estuary and 1.62 ± 0.12 $hr^{-1}$ in beach habitat) and 3.2% resulted in birds standing over the nest (Table 5.2). The remaining encounters resulted in either crouching low on the nest or increased vigilance (neck extended and increased head movement) with few having no response at all. However, for the purposes of determining buffers these were considered "no response" as birds did not leave the nest.

Of encounters resulting in an absence, humans accounted for 65.1%, while natural stimuli were responsible for the remainder. Of all human encounters, 57.8% resulted in nest absences; of all encounters with natural stimuli, 41.9% resulted in absences. Observed and expected frequencies of encounters resulting in an absence were compared to determine whether different stimuli (human, human with pet, vehicle, and natural) elicited different responses by incubating birds. Overall, observed frequencies differed significantly from expected frequencies of nest absences ($X^2$ =120.81, DF = 3, $p < 0.001$). Human stimuli (with and without pets) produced a higher than expected likelihood of nest absence, whereas a lower than expected frequency of absence was observed for vehicles.

**Table 5.1**: Percentage of encounters with various stimuli while incubating.

| Stimuli | Percentage of encounters (%) | | |
|---|---|---|---|
| | Estuary (n=74) | Beach (n=453) | All (n=527) |
| Recreation on dune | 10.8 | 4.9 | 5.7 |
| Recreation on high/mid beach | 1.4 | 6.8 | 6.1 |
| Walker low beach without dog | 29.7 | 3.5 | 7.2 |
| Swimmers/fishers | 9.5 | 9.9 | 9.9 |
| Recreation on high/mid beach with dog(s) | 4.1 | 2.9 | 3.0 |
| Walker(s) low beach with dog | 9.5 | 3.8 | 4.6 |
| Vehicle pass | 5.4 | 14.3 | 13.1 |
| Vehicle park | 1.4 | 6.8 | 6.1 |
| Motor cycle | 0.0 | 0.9 | 0.8 |
| Rider on horse | 0.0 | 1.3 | 1.1 |
| **Human Totals** | 71.6 | 55.2 | 57.6 |
| Intruding Australian Pied Oystercatcher | 5.4 | 7.5 | 7.2 |
| Kite and Osprey [1] | 8.1 | 16.6 | 15.4 |
| Eagle [2] | 2.7 | 9.5 | 8.5 |
| Crow [3] | 2.7 | 4.0 | 3.8 |
| Gull [4] | 2.7 | 3.1 | 3.0 |
| Other bird species [5] | 4.1 | 2.2 | 2.5 |
| Australian Magpie [6] | 2.7 | 0.9 | 1.1 |
| Migrant bird species [7] | 0.0 | 1.1 | 0.9 |
| **Natural Totals** | 28.4 | 44.8 | 42.4 |

Note: [1]*Haliastur indus, H. sphenurus, Elanus axillaris, Falco cenchroides* and *Pandion haliaetus.* [2]*Haliaeetus leucogaster.* [3]*Corvus orru*, [4]*Larus novaehollandiae*, [5]*Vanellus miles, Pelecanus conspicillatus, Merops ornatus* and *Haematopus fuliginosus*, [6]*Gymnorhina tibicen*, [7]*Limosa lapponica* and *Numenius phaeopus.*

Observed and expected frequencies were also compared for each of the stimulus categories (where expected frequencies were greater than five). Observed frequencies of nest absence differed significantly to expected frequencies for most stimuli. Frequencies of nest absences were significantly higher than expected for human recreation on dune, high/mid and low beach zones, and also for human stimuli with dogs (Table 5.2). However, vehicle passes were observed to cause substantially lower frequencies of absences than expected. Of natural stimuli, eagles caused a significantly greater than expected frequency of nest absence, while kites, crows and gulls all caused a significantly less than expected number of absences (Table 5.2).

**Table 5.2**: Number of encounters with a variety of stimuli during hour-long observations of incubating Australian Pied Oystercatchers (pooled across pairs), and number that caused either a standing or departure/absence response. Expected frequencies, calculated using chi-squared analysis, for nest absences in response to these stimuli are also presented, along with the chi-squared value and associated p-value.

| Stimuli | n | Number observed to cause standing | Number observed to cause absence | Number expected to cause absence | $x^2$ | p |
|---|---|---|---|---|---|---|
| Recreation on dune | 30 | 1 | 25 | 15.36 | 12.41 | 0.001 |
| Recreation on high/mid beach | 32 | 5 | 25 | 16.38 | 9.29 | 0.010 |
| Walker low beach | 38 | 1 | 27 | 19.45 | 6.00 | 0.050 |
| Swimmers/fishers | 52 | 3 | 35 | 26.62 | 5.41 | ns |
| Recreation on high/mid beach with dog | 16 | 0 | 16 | 8.19 | 15.26 | 0.001 |
| Walker(s) low beach with dog | 24 | 1 | 22 | 12.28 | 15.74 | 0.001 |
| Vehicle pass | 69 | 1 | 5 | 35.32 | 53.32 | 0.000 |
| Vehicle park | 32 | 0 | 12 | 16.38 | 2.40 | ns |
| Motor cycle | 4 | 0 | 2 | | | |
| Rider on horse | 6 | 0 | 6 | | | |
| **Human Totals** | 303 | 12 | 175 | | | |
| Intruding Australian Pied Oystercatcher | 38 | 1 | 18 | 19.45 | 0.22 | ns |
| Eagle | 45 | 1 | 39 | 23.03 | 22.67 | 0.000 |
| Kite | 81 | 2 | 30 | 41.46 | 6.49 | 0.050 |
| Migrant | 5 | 0 | 2 | | | |
| Other birds | 13 | 0 | 4 | 6.65 | 2.17 | ns |
| Crow | 20 | 0 | 0 | 10.24 | 20.97 | 0.000 |
| Gull | 16 | 0 | 1 | 8.19 | 12.93 | 0.000 |
| Magpie | 6 | 1 | 0 | | | |
| **Natural Total** | 224 | 5 | 94 | | | |

Note: Only stimuli that produced expected values of greater than five were included in analyses. Expected frequencies assume an equal probability of initiating a nest absence. Only significant (≤ 0.05) p-values have been presented.

### *5.4.4 Duration of nest absences*

Overall, lost incubation time averaged 12.87 (± 1.04) mins hr$^{-1}$ (or 21.5% of time). Lost time for estuary nesters averaged 11.04 (± 2.31) mins hr$^{-1}$, and 13.22 (± 1.16) mins hr$^{-1}$ for beach pairs, ranging from 0 to 60 mins hr$^{-1}$ of disturbance (Table 5.3). Although surveys were undertaken in one hour bouts, in one case a pair was observed until the bird was able to continue incubating. The total time spent off the nest was 1 hour 24 minutes - note however, that only the hour was included in analysis. Human stimuli (with and without pets, and including vehicles) were responsible for 83.1% of all time that was spent off nests. The remaining 16.9% of time was due to natural stimuli (Table 5.3). The longest average nest absence lasted 23 minutes and was caused by recreation on the mid-high beach involving a dog. Recreation on the mid-high beach and dune along with fishing and swimming activities similarly resulted in prolonged nest absence (Table 5.3).

To determine whether different stimuli resulted in different periods of nest absence, analysis of variance was undertaken on log-transformed data. Overall, the various disturbance stimuli created significantly different periods of nest absence ($F_{[12,259]} = 12.10$, $p < 0.001$), and grouped together, human disturbance resulted in significantly longer absences than natural disturbances ($F_{[2,258]} = 12.02$, $p < 0.001$). Multiple post-hoc comparisons were made to determine which specific disturbance factors were most threatening. Human disturbance factors, including roaming activity (swimming/fishing), use of mid/high beach zones and foredune/dune zones, regardless of whether a pet was present during an encounter, caused a significantly prolonged nest absence as compared to natural stimuli (Table 5.4). Passing vehicles similarly had a significantly reduced impact upon nest absence as compared to these other factors (Table 5.4). Walking on the lower beach zone (without dogs) also resulted in a significantly reduced impact compared to recreation on the mid/high beach (with dogs), also compared to recreation on dunes (without dogs). Walking on the lower zone with a dog resulted in a reduced response as compared to walking with a dog on the mid/high zone (Table 5.4). Hence, human activity on the lower zone had a reduced response compared to activity in other zones. Nonetheless, human activity was still more detrimental, in terms of lost time, than natural stimuli.

**Table 5.3**: Maximum and average duration (also standard error) of absences, in minutes, in response to single stimuli of various types. Total time spent off nests in response to these stimuli is also presented, along with the percentage of total time that was lost due to each stimulus. Total survey hours = 176.

| Stimuli | Maximum duration of absence (mins) | Average duration of absence (mins) | Standard error of absence (mins) | Total time (mins) | % of time |
|---|---|---|---|---|---|
| Recreation on dune | 60 | 11.88 | 2.41 | 297 | 13.11 |
| Recreation on high/mid beach | 29 | 12.00 | 1.33 | 312 | 13.77 |
| Walker low beach | 18 | 7.30 | 0.80 | 197 | 8.70 |
| Swimmers/fishers | 40 | 11.51 | 1.40 | 403 | 17.79 |
| Recreation on high/mid beach with dog | 60 | 23.00 | 3.61 | 345 | 15.23 |
| Walker(s) low beach with dog | 21 | 9.64 | 1.29 | 212 | 9.36 |
| Vehicle pass | 5 | 2.00 | 0.78 | 10 | 0.44 |
| Vehicle park | 12 | 4.08 | 0.94 | 49 | 2.16 |
| Motor cycle | 11 | 9.00 | 2.00 | 18 | 0.79 |
| Rider on horse | 14 | 6.67 | 1.76 | 40 | 1.77 |
| **Human Totals** | 270 | 97.08 | 16.32 | 1883 | 83.12 |
| Intruding Australian Pied Oystercatcher | 9 | 3.78 | 0.54 | 68 | 3.00 |
| Eagle | 18 | 4.35 | 0.57 | 170 | 7.51 |
| Kite | 14 | 4.17 | 0.56 | 125 | 5.52 |
| Migrant | 4 | 2.50 | 1.50 | 5 | 0.22 |
| Other birds | 5 | 3.25 | 0.75 | 13 | 0.57 |
| Crow | 0 | 0.00 | 0.00 | 0 | 0.00 |
| Gull | 1 | 1.00 | 0.00 | 1 | 0.04 |
| Magpie | 0 | 0.00 | 0.00 | 0 | 0.00 |
| **Natural Totals** | 51 | 19.05 | 3.92 | 382 | 16.86 |

**Table 5.4**: Summary matrix of results of pair-wise Tukey's tests comparisons made between periods spent off the nest in response to disturbance factors.

| | Human | | | | Human with dog | |
|---|---|---|---|---|---|---|
| | Swimmer/ fisher | walker low beach | Recreation mid/high | Recreation dune | Recreation mid/high with dog | Walker low beach with dog |
| **Human** | | | | | | |
| Swimmer/fisher | | | | | | |
| Walker on low beach | ns | | | | | |
| Recreation on high/mid beach | ns | ns | | | | |
| Recreation on dune | ns | ns | ns | | | |
| **Human with pet** | | | | | | |
| Recreation on high/mid beach with dog(s) | ns | *** | ns | ** | | |
| Walker low beach with dog(s) | ns | ns | ns | ns | ** | |
| Rider on horse | ns | ns | ns | ns | * | ns |
| **Natural** | | | | | | |
| Intruding Australian Pied Oystercatcher | *** | ns | *** | ** | *** | ** |
| Eagle | *** | * | *** | *** | *** | ** |
| Kite | *** | ns | *** | *** | *** | ** |
| **Traffic** | | | | | | |
| Vehicle pass | *** | ** | *** | *** | *** | ** |
| Vehicle park | *** | ns | *** | * | *** | ns |

Note: Overall ANOVA result was $F_{[12,259]} = 12.10$, $p < 0.001$, all pair-wise combinations were tested (for factors where the number to cause an absence ≥ five). *** indicates p-value of ≤ 0.001, ** indicates p-value of ≤ 0.010, * indicates p-value of ≤ 0.050 and ns indicates non-significant result.

Of time spent incubating (78.6% of time), duties were not shared equally. Males incubated for an average of 37.4%, while females were responsible for 62.7% of observed incubation time. Disturbance also affected the non-incubating partner close by the nest, with an average of 11.02 (± 1.21) mins $hr^{-1}$ (18.4% of time) lost from other activities, including foraging and roosting (n = 134 observation hours). However, periods of disturbance to foraging and roosting birds averaged 12.09 (± 1.35) mins $hr^{-1}$ for beach birds and 2.57 mins (± 0.74) $hr^{-1}$ for estuary birds.

Voluntary absences, such as in the process of incubator change-over, were also recorded, averaging 2.41 (± 0.33) mins per absence, thus were substantially reduced periods compared to human-induced absences (change-over of incubators averaged 2.13 $hr^{-1}$). Time lost incubating as a result of observer created disturbance while checking nests (outside of hour-surveys), was also substantially less than that due to other disturbance events ($F_{[13,304]} = 12.92$, $p < 0.001$). Nest absences in response to observer disturbance were comparable to times resulting from natural stimuli (APOCs and White-bellied Sea Eagles), and far less than those due to human disturbance.

### *5.4.5 Response distances*

Human stimuli were used to examine response distances as these created the greatest number of nest absences (human n = 79, human with dog n = 20). Birds became alert and vigilant at an average distance of 139.0 (± 13.10) m on the approach of humans and 200.0 m (± 0.00) for humans with dogs. The average distance at which birds left the nest in response to human disturbance was 80.56 m (± 8.44), but was significantly greater (128.84 m ± 20.11) when humans were accompanied by dogs ($F_{[1,56]} = 4.01$, $p = 0.008$).

Calculations of desired buffer distances, defined by the upper limit of an approximate 95% confidence interval around the mean (distance at which birds left the nest), indicate that approximately 193.90 m would provide protection for most incubators from recreationalists. However, in areas where dogs are permitted, this should be increased to approximately 273.70 m.

## 5.5 Discussion

### *5.5.1 Impacts of anthropogenic and natural disturbance*

Australian Pied Oystercatchers were disturbed frequently during incubation, at a rate exceeding that at which others have previously suggested increases mortality of oystercatchers (Goss-Custard *et al.* 2006). The majority of all disturbance events, including those that caused an absence, were human (including traffic). Human recreational disturbance had a significantly higher impact on incubation than natural stimuli. Of the 21.5% of total time spent off nests in response to disturbance, 83.1% was due to human activity. Hence, human disturbance constitutes a management issue at APOC breeding sites in northern NSW.

Recreational activity including walking on dunes and mid/high beach, roaming activities, swimming and fishing from the beach, were all disturbing to incubating APOCs. Hence, humans elicited defensive responses in parents resulting in increased energy demands and absence from nests, potentially resulting in eggs becoming more vulnerable to predators and to over-heating. Similar results have been reported previously by Papouchis *et al.* (2001), Finney *et al.* (2005), Pearce-Higgins *et al.* (2007) who all suggest that roaming movement, activity that is not predictable, is most disturbing to species. All found that when activity was restricted and predictable, such as walkers moving along a set path, responses were reduced.

However, the zone of beach used by humans affected the level of disturbance. Walkers on the lower beach (wet sand) were least threatening, resulting in less time off nests than other recreational activities, especially those higher up the beach. This is not only because they were further from nest sites, but also because movement was more predictable and less erratic, i.e. walkers exercising rather than recreationalists roaming. Although swimmers and fishers also generally occur lower on the beach, they do roam into other zones, i.e. back to vehicles, bait and towels, thus, they also posed a greater threat to birds than walkers. However, activity above the mid/high beach, closer to nests, was most disturbing. Others have also previously indicated that nests of upland breeding birds situated closer to walking trails experienced more disturbance and were more likely to fail than those further from them (Murison *et al.* 2007). Such disturbance is not only detrimental while incubating, but may interrupt pre-laying and laying phases and can delay egg-laying at traditional sites, which also has implications for success and survival (Hobson and Hallinan 1981, Erwin 1989, Murison *et al.* 2007).

People with dogs were far more disturbing than people alone. Dogs on the mid/high beach resulted in the longest nest absence caused by any disturbance. In fact, the presence of dogs in those areas caused birds to remain off nests for twice as long as most other threatening activities. Oystercatchers also left their nests much earlier (at greater distances), in response to dogs than to any other stimuli. Hence, dogs had a major impact on incubation. These results concur with others who previously found that birds and ungulates flushed more readily in response to dogs than people or vehicles (MacArthur *et al.* 1982, Yalden and Yalden 1990, Lord *et al.* 2001) and also, that birds remain off eggs for longer when disturbed by dogs (Taylor *et al.* 2007). Such strong responses to dogs are not surprising as canids are traditional predators of ground-nesting birds (MacArthur *et al.* 1982). Furthermore, pets often brought to nest sites by humans have previously been identified as the cause of chick losses (Moffatt 2005, Chapter 4) while foxes (*Vulpes vulpes*), also depredate eggs.

Although four-wheel-drive vehicles have received much attention for their negative impact upon beach morphology, flora and fauna (Godfrey *et al.* 1978, Hosier 1981, Luckenback and Bury 1983, Wolcott and Wolcott 1984, Carlson and Godfrey 1989, Moffett *et al.* 1998), vehicles below the high water mark were less likely to disturb incubating oystercatchers than other human recreation. Similarly reduced responses in comparison to dogs and humans have also previously been reported in other environments, for ducks and sheep (MacArthur *et al.* 1982, Klein 1993, Papouchis *et al.* 2001, Pease *et al.* 2005). Although vehicle traffic is a lesser cause of nest absence than other recreational activities, traffic remains a threat to incubating birds in other ways. Vehicles facilitate access of recreational users to areas of the beach away from paths, spreading disturbance to further nest sites. Furthermore, although no evidence was found of vehicle impact on incubating birds, vehicles do pose the risk of crushing nests and chicks if driven above the high tide mark (Harrison 2005, Appendix B). Vehicles have also collided with and killed breeding adults at the waters edge while foraging, with consequent loss of chicks (Harrison 2005, Moffatt 2005, Chapter 4). Chicks may also be crushed when foraging on the seaward side of the high tide mark, when sheltering in dunes or when sheltering on the beaches in vehicle tracks (Melvin 1994, Harrison 2005). Consequently, vehicles must be carefully managed to protect not only nesting but brooding birds and their chicks. In some cases, the real impacts of vehicles may not be evident until vehicles are removed; in South Africa following the banning of off-road vehicles on beaches the number of shorebirds, number of breeding pairs and productivity all increased immediately and dramatically, providing strong evidence to continue the ban (Williams *et al.* 2004).

Natural stimuli generally resulted in less frequent and shorter periods of nest absences than human disturbance. However, oystercatchers did respond strongly to White-bellied Sea Eagles, probably because they are known to attack both immature and adult oystercatchers (Marchant and Higgins 1993, Chapter 4).

The limited response of oystercatchers to the Torresian Crow, a known egg predator (Cresswell and Whitfield 1994, Chapter 4), may be related to predator behaviour. Crows may not necessarily drive birds off nests in search for eggs, nor be a direct threat to adults as for the fox (*Vulpes vulpes*), rather they may scavenge unattended nests opportunistically.

Raptors flying along beaches do flush oystercatchers, and while walking along beaches is the least disturbing human activity this has potential to increase the frequency of raptor activity. Flushing of raptors may then lead to flushing of successive APOC pairs, which may then also move into neighbouring territories (A. Harrison pers. obs.). Consequently, conspecific interactions then also increase, as do the energetic costs for neighbouring nesting oystercatchers (Burger 1991). Activities such as fishing also have potential to exacerbate this, as discarded bait and by-catch attracts scavenging birds, such as gulls, crows, sea-eagles and kites. The attraction of these species may increase disturbance and risk of predation to breeding oystercatchers, and may continue long after the initial disturbance, i.e. after fishermen have left the beach (Knight *et al.* 1991).

Partnered shorebirds often remain in visual contact while incubating and feeding and may cooperate in defence of territories, eggs and chicks (Burger 1991, Totterman and

Harrison 2007 see Appendix A). Adequate defence relies upon both partners (Burger 1991). Consequently, disturbance in nesting territories results not only in nest absence but lost foraging time for partnered birds. This has potential to reduce fitness of both partners. Here, foraging partners lost approximately 18% of time due to disturbance. Unlike non-breeding migratory species, territorial breeders are constrained to a limited area of habitat with the responsibilities of incubation and defence. Foraging time is also limited, dictated by tides, and by size of highly defended territories. Therefore, increased time spent in defence is at the expense of other activities and is difficult, with birds subsequently incurring stress costs while trying to compensate for lost time (Burger 1991, Goss-Custard *et al.* 2006, Stillman *et al.* 2007).

*5.5.2 Different responses between habitats*

Evidently, APOCs occurring in different habitats behave differently, here estuary birds flushed in response to the observer at significantly greater distances than beach birds, also returning to their nests when the observer had retreated to greater distances than for beach birds, resulting in estuary birds spending longer periods off the nest. Furthermore, estuary birds were cryptic in their behaviour, leaving the nest by walking, while beach birds more often fly. Such behavioural difference may in part also explain the observed difference in reproductive success between habitats (Chapter 4). Previously pairs that return to the nest faster following human disturbance have been found to have much lower hatching success (Yasué and Dearden 2006). Skutch's hypothesis also suggests that nests with higher visitation rates by parents may incur higher predation rates (Skutch 1949, 1961). Hence, pairs that exhibit distraction displays or hide away from the nest for longer, in response to threats such as disturbance and predation, are more likely to attain higher hatching success, by avoiding predator detection of nests (Blancher and Robertson 1982, Byrkjedal 1987). Predation rates were higher at beach sites where birds remained off the nest for shorter but more frequent periods.

Habituation, as a result of more frequent encounters with humans (Burger and Gochfeld 1983, Gochfeld 1984, Yasué and Dearden 2006), may in part explain the shorter approach distances and shorter period off the nest exhibited by beach birds. Beach birds were disturbed slightly more frequently than estuary pairs. Furthermore, the studied beach nesting APOCs have experienced regularly observer approaches (close to the nest) over the past decade as part of the NPWS fox baiting and APOC monitoring program (Wellman *et al.* 2000, Totterman and Harrison 2007). Constant nest checking may have conditioned the birds to short approach distances, and had the unexpected negative affect of drawing further attention to nest sites. Such activity also causes a flight response, owing to the delayed escape, more often in beach birds, which is considered by Pease *et al.* (2005) to be more disturbing than other responses as it equates to higher energetic output. Pairs that are disturbed more frequently also suffer interrupted foraging, which can be detrimental to reproductive potential and survival in intertidal habitats (Lord *et al.* 1997, Verhulst *et al.* 2001, Goss-Custard *et al.* 2006). Hence, unneccesary activity at nest sites should be avoided. Additional energy expenditure by beach pairs may have also contributed to reduced breeding success (Chapter 4) in that habitat. Estuarine nesters on the other hand, have received little research attention to date and remain cryptic, have a lower predation risk and higher productivity.

Distances at which birds flushed from the nest in response to observer disturbance were lower overall than for responses to other human disturbance. This may also be related to habituation, particular for beach birds, however, possibly also to angle of approach (Fernández-Juricic *et al.* 2005).

### *5.5.3 Management implications*

Australian Pied Oystercatchers nesting in northern NSW suffer frequent disturbance due to human activity, which has a significant impact on time spent incubating, caring for chicks and foraging. Although Gill *et al.* (1996, 2001, 2007) suggests that population consequences need be demonstrated, this may be difficult for such small populations. It is reasonable to assume that human disturbance does have a detrimental impact on APOCs breeding success, productivity and foraging efficiency, therefore, potentially also on the population. Because coastal residents such as the vulnerable APOC do face continuing pressure from increased urbanisation and the threat of sea level rise destroying habitat, and given that they are few in number and are continuing to decline (Chapter 3), minimising the frequency and severity of human disturbance in remaining breeding areas should be of primary concern.

Dogs have been identified as more disturbing to incubating APOCs than people alone. Hence, strict control of dogs on beaches and within estuaries is required, particularly in the breeding season. Nesting areas should be strictly “no dogs” areas. At South Ballina Beach, where the majority of beach nesting pairs breed, a dog exercise area should be enforced that is limited to an area where pairs do not breed.

To minimise close-approach and recreational disturbance during incubation, sign-posted buffers with a radius of 194 m should be enforced surrounding nests and be made strictly "no stopping" areas. Given that beaches are often narrow, less than 200 m wide during low tide period, this may essentially require the closure of sections of beaches, in which vehicles may pass slowly, but should not stop and should not be accessed on foot. Recreational activities most threatening to APOCs, close-proximity activity on dunes and high beach areas (within approximately 10 m of the dune), should be minimised generally also to protect habitat, and mitigate shoreline retreat resulting from sea-level rise, storm activity and associated erosion (Carlson and Godfrey 1989). To ensure that disturbance remains minimal at traditional nesting sites in the long-term, local council should include provisions in their development control plans or local environment plans that limit the use of inappropriate access paths to the beach, particularly South Ballina Beach, thus minimising disturbance to threatened species in the future. The effectiveness of fox baiting and the required frequency and timing (during bait/survey day) of activity at nest sites should be carefully considered, monitored and evaluated to also ensure minimal disturbance to nest sites.

Community education, via signage, and provision of educational material, is also necessary to ensure change. Monitoring to evaluate education efforts and compliance with buffers now in place (DoL 2007) is also recommended to determine the effectiveness of suggested measures for this population.

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## CHAPTER 6
General discussion

### 6.1 The original intent

The Australian Pied Oystercatcher (*Haematopus longirostris*) and Sooty Oystercatcher (*H. f. fuliginosus*) are shorebirds listed as vulnerable species in New South Wales (NSW) (Schedule 2 of the *Threatened Species Conservation Act* 1995), with only 250-480 and 200 individuals for each species estimated respectively in the state (Smith 1991, Watkins 1993). Both are threatened by habitat loss, predation, human encroachment and disturbance (Lane 1987, Smith 1991, Newman 1991, Priest *et al.* 2002). Yet, few detailed studies have been undertaken on either species, and what has been done, has generally focused on secure populations elsewhere in Australia (Newman 1992, Lauro and Nol 1995a, 1995b, Minton 1997, Kraajijeveld-Smit *et al.* 2001, 2004). This thesis sought to examine the abundance, population trends, distribution, key habitat requirements and breeding biology of both species in sub-tropical northern NSW. It was also an objective to identify key threatening processes within the region, to assess the impact of these threats on each species and to provide guidance for future management, i.e. what recovery goals should be set? These aspects are all of critical importance in understanding population dynamics and the limitations on species. In this final Chapter I synthesise information from each of the preceding Chapters and also undertake a basic population analysis for the Australian Pied Oystercatcher population to understand better the mechanisms of population decline. Owing to the limitations involved with surveying the Sooty Oystercatcher (few breeding pairs present and difficulty of accessing offshore nest sites regularly) fewer data were collected. Therefore, no population analysis has been undertaken for that species. Hence, the first two sections deal with both species, but the remaining sections deal only with the Australian Pied Oystercatcher.

### 6.2 Abundance and population trends

The number of Australian Pied Oystercatchers was estimated to be 129 birds in 2003, of which approximately 67% (86 birds) were resident pairs (occupying territories). However, by 2005, despite the production of 51 fledglings (Chapter 4), only 112 birds were estimated to be present (Chapter 3). Comparisons with previous population estimates indicate a sharp decline since the late 1990s, which evidently continued through to 2005, with a net decline of 13% between 2003 and 2005. Declines between these latter years were evident in all cohorts, floaters (down 33%), breeding pairs (17%) and non-breeding territory holders (5%), indicating that older more experienced breeders were lost, and only partly replaced by floaters; also that the number of potential breeders (floaters) had declined substantially (Chapter 3). As found for the endangered Chatham Island Pied Oystercatcher (*H. chathamensis*, Schmechel 2001), some pairs held territories but did not attempt to breed, possibly indicating that they were immature, too old, or that habitat quality was poor (Dhondt 1985, du Plessis *et al.* 1995, Arnold and Owens 1998). Banded birds between four and seven years old defended breeding territories (Chapter 3), supporting the impression that older birds are being lost at a high rate. New breeders are generally excluded from premium territories by more dominant individuals (Ens *et al.* 1992, Heg *et al.* 2003).

The Sooty Oystercatcher was scarcer than the Australian Pied, with an estimated population on the north coast of only 45-59 birds (Chapter 2). Unlike the Australian Pied population, the majority of Sooty Oystercatchers were floaters. Although twenty-six residents were present, only six pairs attempted to breed each year (Chapter 2). Hence, despite apparently good productivity (Chapter 2), recovery potential remained poor. However, comparisons to past estimates (Australasian Wader Study Group unpublished data) indicate that the northern NSW population has remained fairly stable since at least 1996, suggesting that limiting factors contributing to declines may not be as pressing for this species compared to the Australian Pied Oystercatcher, or that they are able to better cope with threatening processes. However, the reliability of past estimates may not be high for this region.

### 6.3 Distribution and habitat use

The majority of Australian Pied Oystercatchers occurred on beaches in the north of the region, north of the Clarence River, nesting primarily along South Ballina Beach (17 of 41 total pairs in 2005), with nests as little as 250 m apart. South of the Clarence River, fewer pairs occurred, and those birds used estuarine habitat for nesting more than beaches.

Key habitat factors determining presence of Australian Pied Oystercatchers primarily included food availability (increased abundance of beach bivalves *Donax deltoides*, soldier crabs and polychaetes) as previously indicated by Owner and Rohweder (2003), and beach morphology (gently sloping shores of longer beaches, where favoured food tended to be common) (Jones and Short 1995, Short 2000, Hacking 2008). Vegetative cover of dunes, estuary catchment size (larger) and the level of disturbance at sites (Chapter 3) were also important predictors of presence. As beaches became steeper and shorter along a southward gradient, the density of beach bivalves decreased, and the number of estuaries increased.

Also, within sites of general suitability oystercatchers avoided some areas due to disturbance (Chapter 3), as found by others (Burger 1994, Taylor and Bester 1999, Leseberg *et al.* 2000, Liley and Sutherland 2007).

In contrast to Australian Pied Oystercatchers, the majority of Sooty Oystercatchers occurred south of the Clarence River, where they used wide rocky platforms and headlands for foraging and islands for nesting. In this area, along with the number of estuaries increasing, the number of rocky headlands, platforms and islands also increased (Chapter 2), as did the number of offshore and near-shore islands. Consequently three distinct regions of use were evident for the Sooty Oystercatcher. North of the Clarence River, where the majority of Australian Pied Oystercatchers occurred, was generally not used, south of the Clarence River to Wooli was used primarily by floaters, and the Solitary Islands and adjacent shorelines were used primarily by resident and breeding pairs. Hence, large-scale habitat features determined presence of birds as previously suggested by others (Lane 1987, Chafer 1993). Floaters were found to be very mobile, thus for the majority of the population threats may be avoided by moving to alternative rocky shores. Given that this species also generally breeds on offshore islands, with restricted human access, Sooty Oystercatchers are not subject to the level of disturbance that breeding Australian Pied Oystercatchers endure. Occupation of nesting islands was largely determined by the absence of Silver Gulls, and substantial soil and vegetation. At least one island was identified as suitable that is currently not occupied, suggesting that possibly the population is currently under capacity.

## 6.4 Population parameters and limiting factors for the Australian Pied Oystercatcher

Key parameters driving populations include adult mortality, productivity, and survivorship of immature birds, with changes in any of these having potential to influence populations (van de Pol 2007). Limiting factors, such as predation, habitat quality, parental quality and disturbance drive population parameters (Hockey 1983, Nol 1989, Ens *et al.* 1992, Burger 1994, Goss-Custard *et al.* 1995, Heg *et al.* 2000, 2001, Liley and Sutherland 2007).

### *6.4.1 Adult mortality rate*

Adult mortality for studied population of the Australian Pied Oystercatcher was estimated to be a minimum of 10% annually (17 lost from 86 adults over two years, Chapter 3), in agreement with others (Newman 1984, 1989). However, with an overall decline in numbers observed, despite younger birds replacing older birds (Chapter 3 and 4), it is suspected that the rate of adult mortality was under-estimated. Several other factors also give reason to suspect an under-estimate of mortality. 1) Many birds were un-banded, thus the likelihood of overlooking loss and replacement of birds was high. 2) Disturbance including death via collision with vehicles, also occurred, directly impacting survivorship of shorebirds (Chapter 3), at least in the north of the region, where the majority of pairs occur (Chapter 3 also Appendix B). The frequency of disturbance (Chapter 5) also exceeded the minimum threshold suggested to be sufficient to prevent increased adult mortality of oystercatchers (Goss-Custard *et al.* 2006). 3) Predation pressure has been historically high (NPWS 2003) and has potential to have a high impact on adult survivorship, at least one beach bird was found though to have been killed by a fox during the 2005 breeding season (Chapter 3). Additionally, 4) food resources (*Donax deltoides*) on ocean beaches, have undergone a dramatic decline (by 70% between 2003 and 2005, Chapter 4) resulting in pairs spending significantly greater periods foraging in 2005 than 2003 (Harrison unpublished data). During 2005, almost double the time was spent foraging than has previously been suggested necessary for a bird of this size (Dann 1987). Similar threatening processes (disturbance, predation and reduced habitat quality) have recently also resulted in an increased estimate of adult mortality for the Eurasian Oystercatcher (*H. ostralegus*) (Le V. dit Durell 2007).

*6.4.2 Reproductive rate*

Hatching success (47%), fledging success (51%) and productivity per pair per year (0.60) for the Australian Pied Oystercatcher, were similar to that reported for oystercatchers elsewhere (Hockey 1983, Nol 1989, Ens *et al.* 1992, Davis *et al.* 2001, Schmechel 2001, Yèsou *et al.* 2001, Jarman and Keating 2006) and similarly varied between years and between habitat types (Chapter 4). Productivity per breeding pair was significantly different between beach (average 0.31 fledglings per pair over three years) and estuarine (average 0.90 fledglings per pair over three years) habitats, with estuarine pairs producing approximately 70% of all fledglings (Chapter 4). Differences in reproductive success of oystercatchers between the habitats have also been found by others (Nethersole-Thompson 1986, Ens *et al.* 1992, Newman 1992, Davis *et al.* 2001, Yèsou *et al.* 2001, Jarman 2006). Birds breeding on beaches were less productive due to higher nest predation (Chapter 4), poorer food supply (Chapter 4), greater disturbance by humans (Chapter 5) and possibly because there were more young inexperienced birds there (Chapter 3).

Beach and estuarine nesting micro-habitats were also different (Chapter 4), with each subject to different–risks. Beach nests were placed on the edge of dunes in areas with significantly less vegetative cover, in open areas with more bare sand, than estuarine birds.

Thus, beach nests were highly visible and likely susceptible to generalist predators (Sheldon *et al.* 2007), in part explaining the significant loss of eggs to foxes in that habitat. Estuarine nests on the other hand, were not only surrounded by more cover, but were often on soil rather than sand, contained more lining and were beneath tall (> 1 m) vegetation (Chapter 4), thus were less visible among structurally complex habitat and potentially provided greater cover for small chicks. However, placing nests in this environment resulted in higher susceptibility to tidal flooding (Chapter 4).

Prey resources on ocean beaches had been dramatically reduced, coinciding with a reduction on beaches between years in chicks fledged (57% in 2003, c.f. 21% in 2005), overall productivity (0.63 c.f. 0.27) and an increase (by approximately 11 days) in fledging period, indicating that growth rates may have also been impacted (Chapter 4). Conversely, prey resources in estuarine habitat, not targeted by commercial fishers, actually increased between 2003 and 2005 (Chapter 4); no change was evident in fledging rate or productivity in estuaries between these years.

Estuary nesters were slightly less affected by disturbance, with an average of 11.0 minutes/hr compared to 13.2 mins/hr lost incubating per hour on beaches (Chapter 5). However, when incubating birds were disturbed, foraging partners were also affected and beach partners lost significantly (20.2%) more time due to disturbance than estuarine partners (4.3%, Chapter 5). Given that beach nesters were already limited by a reduced food supply (and time available for foraging due to tides), disturbance would have further reduced the ability of parents to feed their off-spring (Goss-Custard *et al.* 2006, Stillman *et al.* 2007). When a beach parent was killed during 2005, the other parent was unable to provide sufficient food for the chick; which perished within days.

### *6.4.3 Population consequences*

Historically, oystercatchers occupying beach sites have had very poor breeding success, with few fledglings produced at all north of the Clarence River prior to 1997, when fox control measures were implemented by the state government (Wellman *et al.* 2000, Totterman and Harrison 2007). Low productivity over many consecutive years means that as birds age and die there are few recruits to replace them. Furthermore, new breeders are also younger than would normally be the case, and hence have even lower breeding success (Ens *et al.* 1992, van de Pol *et al.* 2006, van de Pol 2007). Also, fitness prospects of parents are important for life-history evolution and population ecology (van de Pol 2007). Thus, with factors reducing adult fitness and affecting survivorship, population consequences including a decline will follow (Ens *et al.* 1992, Harris *et al.* 1994, Perrins and McCleery 2001, Cam *et al.* 2003, van de Pol *et al.* 2006, van de Pol 2007).

### *6.4.4 Survival of immature birds*

Unfortunately, the rate of survival from fledging to breeding age (4+ years) is currently unknown for this population as are the rates of emigration and immigration. Estimates of survival to breeding for the Eurasian Oystercatcher (*H. ostralegus*), suggest 37-38% survival (Ens *et al.* 1992, Kersten and Brenninkmeijer 1995) and more recently, only 31.9% for this species when occupying poor quality habitat (van de Pol *et al.* 2006b). The only estimate for the Australian Pied Oystercatcher (in Tasmania) suggests the much lower value of 15% (Newman 1989). However, application of survival rates from other populations in undertaking population analysis has been shown to be inappropriate, and can produce unrealistically optimistic projections of sustainability, when in fact a decline was observed (Yèsou *et al.* 2001). Information on survival to breeding age is of priority for future research in the northern NSW population of Australian Pied Oystercatchers. In the interim however, placement of alpha-numeric yellow leg-flags (starting 2006) has begun for pre-fledgling chicks within the region (G. Clancy pers. comm.). Although this is recent, re-sighting records from young banded in 2006 indicate that at least 30% of fledged juveniles (8 of 26) survived their first year (G. Clancy unpublished data). With accumulating losses each year, this would likely equate to an overall survival to breeding age of ≤ 15%, in agreement with Newman (1989).

## 6.5 Calculations of the finite rate of increase: population sustainability

The finite rate of increase (λ) was calculated for the north coast population of the Australian Pied Oystercatcher, using the equation described by Zanette (2000): $\lambda = S_f + N_i \times S_i$, where: $S_f$ = annual survival of female breeding adults, $N_i$ = number of female fledglings produced per female per year (assuming a 1:1 sex ratio of fledglings) and $S_i$ = survival of young to breeding age (based on Newman's (1984) estimate for the Australian Pied Oystercatcher). When populations are exactly replacing themselves $\lambda = 1.0$, when they are increasing $\lambda > 1.0$ and when they are declining $\lambda < 1.0$. This formula is a simplified version of that applied to Eurasian Oystercatchers (*H. ostralegus*) in France and more recently applied in the Netherlands (Yèsou *et al.* 2001, van de Pol *et al.* 2006).

Based on this calculation, the population of Australian Pied Oystercatchers on the north coast of NSW is not sustainable ($\lambda = 0.945$, where $S_f = 0.90$, $N_i = 0.30$, $S_i = 0.15$), thus supporting the observed evidence of a decline (Chapter 3). Considering variation in breeding success by beach and estuary pairs (Chapter 4), a population decline is still evident (beach $\lambda = 0.923$ and estuary $\lambda = 0.968$). Using the approach that others have taken (Norman *et al.* 1991, Baird and Dann 2006), again an unsustainable result is evident.

To reverse the decline, management goals must be set to facilitate population growth. Therefore, the mechanisms behind decline have been further examined. Given that adult mortality is suspected to be higher than 10% and that increased mortality by only 1-2% can also have dramatic consequences for long-lived populations (Goss-Custard 1980, Danchin *et al.* 1995, Davis *et al.* 2001, Schmechel 2001), I first investigated this. If adult survival is over-estimated by only 1-2%, at the current reproductive rate, management would need to aim at achieving a juvenile survival rate of 40% just to maintain the current population (Table 6.1). However, if adult survival is over-estimated by only 3%, juvenile survival would need to be 50% (Table 6.1). If we maintain productivity at the observed rate and can maintain (or increase) adult survival to 90% (Table 6.1), then the goal for management, i.e. for the population to be maintained or increase, would be to achieve at least 35% of female young (fledglings) surviving to breeding age (Table 6.2). Hence, increasing adult and juvenile survival, while maintaining the currently managed level of productivity, should facilitate sustainability. However, if nothing is done to increase survival, and only 15% of young survive to breeding age, as is suggested by Newman (1984) and other preliminary data (G. Clancy unpublished data), and we assume that 90% of adults survive annually (which is likely not the case), then the productivity needed to achieve stability ($\geq 0.70$ female young produced per female per year), is simply unrealistic (Table 6.2). Hence, management must address not only productivity, but mortality, if population consequences are to be reversed (Heg 1999, van de Pol 2007).

### 6.6 Implications for management

Given that the decline of long-lived species often takes years to become evident (Garnett 1992, Davis *et al.* 2001), but that a decline is very evident (both predicted and observed) on the north coast for the Australian Pied Oystercatcher, this should provide an alarm as to the urgency for active management.

Limiting factors vary between the habitats hence, management must also be varied. Beach pairs face severely limiting factors in comparison to estuarine pairs, with significantly higher fox predation pressure (Chapter 4), primary food resources having undergone a severe decline, possibly in association with pressure from commercial and recreational harvesting of beach bivalves, higher risk of death related to human disturbance (vehicles on beaches, Chapter 3, Appendix B), and limited spatial habitat in which to forage and nest (Chapter 3). Currently, source-sink dynamics may be in play, with the rate of adult decline potentially being greater than the rate of juvenile recruitment for the beach nesting Australian Pied Oystercatchers (Chapter 3 and 4).

**Table 6.1**: Projections of finite rates of increase for the north coast Australian Pied Oystercatcher population, assuming the productivity of female young remains at the average 0.30 per female per year (i.e. $N_i$ = 0.60 /2 = 0.30), at varied adult and juvenile survival rates. Bold values are those where populations are replacing themselves or will start to increase.

| | Adult survival $S_f$ | | | | | | |
|---|---|---|---|---|---|---|---|
| Juvenile survival $S_i$ | 0.90 | 0.89 | 0.88 | 0.87 | 0.85 | 0.80 | 0.70 |
| 0.10 | 0.930 | 0.920 | 0.910 | 0.900 | 0.880 | 0.828 | 0.730 |
| 0.20 | 0.960 | 0.950 | 0.940 | 0.930 | 0.910 | 0.857 | 0.760 |
| 0.30 | 0.990 | 0.980 | 0.970 | 0.960 | 0.940 | 0.885 | 0.790 |
| 0.35 | **1.005** | 0.995 | 0.994 | 0.993 | 0.973 | 0.905 | 0.805 |
| 0.40 | **1.020** | **1.010** | **1.000** | 0.990 | 0.970 | 0.920 | 0.820 |
| 0.50 | **1.050** | **1.040** | **1.030** | **1.020** | **1.000** | 0.950 | 0.850 |
| 0.60 | **1.080** | **1.070** | **1.060** | **1.050** | **1.030** | 0.980 | 0.880 |
| 0.70 | **1.110** | **1.100** | **1.090** | **1.080** | **1.060** | **1.010** | 0.910 |
| 0.80 | **1.140** | **1.130** | **1.120** | **1.110** | **1.090** | **1.040** | 0.940 |
| 0.90 | **1.157** | **1.160** | **1.150** | **1.140** | **1.120** | **1.057** | 0.957 |
| 1.00 | **1.185** | **1.190** | **1.180** | **1.170** | **1.150** | **1.085** | 0.985 |

**Table 6.2**: Projected finite rates of increase for varied rates of production of female young, assuming an adult survival rate ($S_f$ ) of 90% and varying survival rate ($S_i$ ) for young to breeding age.

| Productivity (female young) $N_i$ | λ ($S_i$ = 15%) | λ ($S_i$ = 20%) | λ ($S_i$ = 25%) | λ ($S_i$ = 30%) | λ ($S_i$ = 35%) |
|---|---|---|---|---|---|
| 0.1 | 0.915 | 0.920 | 0.925 | 0.930 | 0.930 |
| 0.2 | 0.930 | 0.940 | 0.950 | 0.960 | 0.965 |
| 0.3 | 0.945 | 0.960 | 0.975 | 0.990 | **1.005** |
| 0.4 | 0.960 | 0.980 | **1.000** | **1.020** | **1.025** |
| 0.5 | 0.975 | **1.000** | **1.025** | **1.050** | **1.055** |
| 0.6 | 0.990 | **1.020** | **1.050** | **1.080** | **1.085** |
| 0.7 | **1.010** | **1.040** | **1.075** | **1.110** | **1.115** |
| 0.8 | **1.020** | **1.060** | **1.100** | **1.140** | **1.145** |

Population modeling indicates that to maintain the current population, juvenile recruitment must be increased, adult mortality must be maintained at no more and preferably less than 10% annually and survival of young to breeding age must be maintained at or increased to at least 35-40%. In the past, management has focused on fox control to increase productivity (Wellman *et al.* 2000), however, this alone, is not enough to reverse the decline (Hetch and Nickerson 1999). There is little point trying to increase the number of eggs that hatch, if young cannot then survive to breeding age, i.e. if floaters do not build up as replacements for dying breeding birds. Similarly, if adult mortality is high and hence turn over within territories is high, but not addressed, this will also affect productivity, as younger inexperienced birds have reduced breeding success (Heg 1999, Ens *et al.* 1992, van de Pol 2007). Ideally, management must aim to address both mortality and productivity.

To meet these management goals, and reverse the long-term consequences of population decline, numerous limiting factors must be either removed or alleviated. Predation was the greatest factor limiting reproductive success, (hatching success) for the majority of pairs hence this should be of primary concern to natural resource managers. Control of foxes, particularly on beach sites must continue to be undertaken in concordance with the NSW Red Fox Threat Abatement Plan (NSW NPWS 2001), and should commence prior to July, and continue throughout the breeding season, to also ensure protection of pre-fledging young. Foxes that take baits are often replaced (Wellman *et al.* 2000, NPWS 2003) therefore strategic planning of alternative control methods may be required. Baiting with distasteful "dummy" eggs during non-breeding periods may be a more effective method than culling existing animals, as resident animals are "taught" to alter their behaviour, through reinforced experience. This would also prevent naïve animals from coming into the breeding area, by maintaining experienced animals (Avery *et al.* 1995). The effectiveness of any baiting or other program must be monitored and evaluated for the purposes of adaptive management. Beach nesting birds in particular have been found to expend more energy through flight responses to observer disturbance and it should also be a priority of management bodies and their contractors to reduce disturbance while undertaking management activities.

Dogs brought to nest sites were the only other identified causes of chick loss and were shown to provide the strongest behavioural responses by incubating birds (Chapter 5). Similarly, human disturbance resulted in egg failure, and was also shown to negatively impact upon incubating birds, causing increased energetic stress, lost incubation time and lost feeding time of partners (Chapter 5), particularly when on the high beach zone. Hence, restriction of dogs and recreationalists from nest sites would also be of benefit in minimising stress and risk of failure. This could primarily be achieved through local councils "local environment plans" and/or "estuary management plans" and collaboration between management agencies. Examination of response distances for various threats revealed that buffers of 194 m are needed around nests, to protect birds from human disturbance in the absence of dogs (Chapter 5). Dogs should be restricted to sections of the beach/estuary where no nesting activity occurs. Buffers should be clearly sign-posted as no-stopping areas, and this applies to both beach and estuarine nesting pairs. At beach sites, this essentially requires small sections to be closed to recreation, due to the narrow area available between the nest and shoreline. Such actions would also benefit partners of incubating birds, via minimising responses to disturbance, i.e. the time lost foraging. Not only this, but it would also provide protection to young pre-fledging chicks. Given that travelling vehicles resulted in less than expected responses by incubating birds, they should be permitted to pass, on the lower beach, but not stop within buffered zones.

However, vehicles have been identified to place birds at risk of death when operated irresponsibly on beaches. Therefore, to reduce unnecessary adult (and chick) mortality, speed limits must be reduced to 30 km/hr (Appendix B), drivers must not drive above the tide mark (remain approximately 10 m below the base of the dune), on dunes or vegetated areas where chicks and nests may be, and drivers must not stop between sign-posted buffers (Chapter 5). Furthermore, drivers must be held accountable for their actions. Hence, a permit system, as a means of controlling the number of vehicles accessing beaches, should be introduced (Appendix B).

The final limiting factor to be addressed, food resources, essentially underpins the survival of the species. Harvesting of the beach bivalve (*D. deltoides*) by the shell-fishery and recreationalists from NSW beaches has direct implications for not only the reproductive success (production and survival of young) of the Australian Pied Oystercatcher, but for adult survival. Despite there being such an evident conflict over natural resource use (between conservation and commercial use), to date, there has been no study conducted to determine the impact of removal, on bivalve populations, or on the impact it may have on oystercatcher populations. This is true despite that removal of key prey resources can result in dramatic declines, as shown for *H. ostralegus* (Atkinson *et al.* 2003, Ens *et al.* 2004). Given that commercial catches of these bivalves have also fallen by 40% over the five years leading to 2005, this should also sound an alarm to the industry. It is strongly recommended that a sustainability study be undertaken determining the viability of harvesting this resource and that this practice cease in the interim.

Although numbers of Sooty Oystercatchers within the region remain lower than for Australian Pied Oystercatchers, the population appears stable. Furthermore, given that the species nests on generally isolated islands, its breeding success does not appear to be as affected as does that of the Australian Pied Oystercatcher. Nonetheless, protection of accessible near-shore nesting islands may be beneficial.

### 6.7 Future research

To determine population trends accurately and the effectiveness of any management actions, it is essential that parameters such as survival to breeding age and adult survival are accurately determined for the immediate population, rather than trying a one-fits-all approach, i.e. applying inappropriate values from other populations. Thus, further colour-banding of young Australian Pied Oystercatchers and Sooty Oystercatchers should be a priority for the future, along with long-term regular counts. Colour-banding and monitoring is also necessary to determine the composition, dynamics and movements of the floater sub-populations. Currently leg-flagging, which is already producing much needed information, has focused on pre-fledging birds only. However, to determine adult mortality it is also now recommended that noose-netting and decoys be used for territorial birds, as has been done successfully for the American Oystercatcher (*H. palliatus*), before or between breeding attempts to capture and mark breeding adults to more accurately determine mortality rates (Mehl *et al.* 2003, McGowan and Simons 2005).

Further investigation of Sooty Oystercatchers is recommended to determine breeding success accurately, age at first breeding and the above mentioned population parameters. As Sooty Oystercatchers also forage on mainland shores where human disturbance may impact their foraging behaviour, investigation of this is also recommended.

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Each of the recommended actions identified in this thesis, in addition to those listed in Appendix B, were submitted to the state government for consideration during the process of developing the recently adopted Threatened Species (Australian Pied Oystercatcher) Management Strategy (DoL 2007). Many recommended actions were included in that document and after much consultation with community groups and state agencies many of these actions are currently being implemented on the beaches of northern NSW.

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## APPENDIX A

A paper published in collaboration with Bo Totterman, who had studied the oystercatchers for many years….

Totterman, B. and Harrison, A. (2007). A long-term breeding trio of Pied Oystercatchers *Haematopus longirostris*. *Australian Field Ornithology* **24**, 7-12.

## APPENDIX B

A report submitted to the NSW Department of Lands during the development of the Threatened Species (Pied Oystercatcher) Management Strategy

Note that the formatting of this report has changed slightly to the submitted version due to variation of pages numbers, which now conform to thesis page numbers. Resulting from this, the table of contents for this report is no longer correctly formatted and does not contain valid page numbers in this thesis format.

Harrison, A. (2005). Impact of Recreation on Shorebirds at South Ballina Beach, Spring 2005. University of New England, National Marine Science Centre, Unpublished Report, submitted to NSW Department of Lands.

Appendices A & B available on request

# APPENDIX C

Educational material produced in an effort to raise awareness of shorebirds, the issues they face and how the community can help, along with a list of further communication including conference presentations and workshops.

# OYSTERCATCHERS:

## On rocky shores, in our estuaries & on our beaches

Pied and Sooty Oystercatchers are listed as *Threatened Species* in NSW. They breed in and around beaches, estuaries and headlands between August and January, with two or three hen sized speckled eggs being laid in scrapes in the sand or pebbles just above the high tide mark. Between Sawtell and Ballina on the north coast there are only around 170 Pied Oystercatchers and 95 Sooty Oystercatchers in total left.

The decline of Oystercatchers is a result of low breeding success which is thought to be a consequence of human disturbance to feeding, nesting and roosting sites, destruction of eggs and chicks by 4WDs, people and pets and, predation by feral and domestic animals. Through research into the impact of these threats and public awareness it is hoped that the future of these species may look brighter.

## You can help our Threatened Species too

- When visiting beaches and estuaries be aware of shorebirds and watch for nesting areas
- Allow a buffer zone between yourself and wildlife, while walking and/or driving on beaches
- Drive slowly & responsibly on beaches
- Be alert for fenced/signed zones established by NPWS to protect breeding shorebirds
- Try to avoid walking, driving and sitting on the dunes and vegetated sand-spits within estuaries - camouflaged eggs may be in these areas
- Ensure your pets cannot roam freely on beaches, estuaries and headlands, particularly at night
- Assist in Fox Control Programs
- Observe bag limits when taking shellfish as bait

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National Marine Science Centre

# The pipi

## An important food source for oystercatchers

**DESCRIPTION**

The pipi belongs to a group of shellfish known as bivalves (two shells joined by a hinge). They are typically smooth in appearance and range in colour from almost white through to yellow, brown and purple.

**BIOLOGY**

Pipis reproduce by spawning, producing huge numbers of young that are dispersed in the ocean. They mature at about 13 months at a length of > 3.6 cm, growing to a maximum length of approximately 6 cm by 3.5 years. They have a total life span of 4-5 years.

**HABITAT AND ECOLOGY**

Pipis are found on open ocean beaches where they occur around 6-10 cm beneath the sand's surface. They are generally more abundant near the low water mark and can sometimes be seen coming to the surface to feed. While the abundance of pipis fluctuates enormously over time and space, they are generally more plentiful during winter.

**Collection of pipis must be undertaken by hand. Mechanical harvesting is prohibited.**

**BAG LIMIT: 50**

**Pipis collected on NSW beaches are for immediate use only as bait.**

**Pipis are not to be taken beyond 50 m of high tide.**

**COLLECTION**

Pipis are commercailly harvested in NSW, including locally at South Ballina Beach. They are harvested to supply bait for fishers and for human consumption. Pipis are considered to be a delicacy by many cultures and indigenous Australians have been collecting and eating them for thousands of years. Pipis are also commonly used as bait by many recreational surf-fishers around eastern Australia and Tasmania.

**IMPORTANT FOOD SOURCE**

Pipis play a crucial role in the coastal food web and are the main food item of the Pied Oystercatcher. Pied Oystercatchers on South Ballina Beach depend almost entirely on the pipi to provide the nourishment they need to survive. During the breeding season pipis are less abundant and the birds spend more time and energy searching for food for themselves and their hungry chicks. During this time the birds are more vulnerable to disturbance.

**HOW TO HELP**

- When collecting pipis, take only what you need for the day.
- Avoid keeping the small pipis (< 3.6 cm) for bait, rebury them so they have a chance to survive.
- Avoid collecting pipis from the beach in Pied Oystercatcher nesting areas.

*For further information please contact:*

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Department of Lands

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Photographs by: Kelley Allen and Annette Harrison

## Seminars and Presentations

Harrison, A. E. (2007). Population trends, breeding biology and sustainability of Pied Oystercatchers (*Haematopus longirostris*) using beach and estuary habitat in northern NSW, Australia. *International Wader Study Group Conference*, La Rochelle, France, September 28th – October 1st, 2007 (oral paper, abstract only).

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**Radio Interviews**

'A better world – Pied and Sooty Oystercatchers – Annette Harrison'
ABC MID NORTH COAST NSW – 3:35 pm, Tuesday, September 2, 2003

'Pied and Sooty Oystercatchers under threat – Annette Harrison '
ABC NEW ENGLAND AND NORTH WEST NSW – 9:25 am Wednesday, September 10, 2003