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A SURVEY OF THE BREEDING SEABIRDS AND MIGRATORY SHOREBIRDS OF THE HOUTMAN ABROLHOS, WESTERN AUSTRALIA

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A complete survey of the numbers and breeding stages of seabirds, resident and migratory shorebirds and raptors at the Houtman Abrolhos Islands, central west coast, Western Australia, was undertaken. One hundred and ninety two (192) islands, islets and rocks were surveyed over 21 days in December 2006.

Seabird nesting habitat was mapped in its entirety for those islands considered as significant breeding areas (i.e. Pelsaert Island, Leo Island) and estimates of both breeding and roosting seabirds were made for each island. Notes on the stage of breeding were also taken, and where applicable, eggs were measured and weighed for some species to obtain breeding dates. Monitoring transects were established on West Wallabi and Pelsaert Islands to monitor longer-term changes in the nesting density of the Wedge-tailed Shearwater *Ardenna pacifica,* Lesser Noddy *Anous tenuirostris melanops,* Common (Brown) Noddy *Anous stolidus* and Sooty Tern *Onychoprion fuscata.* The Lesser Noddy transects had been previously established by Fuller and Burbidge (1992), and were used again for comparative purposes.

We recorded 14 species of seabirds, 16 species of migratory shorebirds, three resident shorebirds and two raptors during this survey. Of these, 14 species of seabirds, three resident shorebirds and the two raptors were breeding. These breeding populations are considered significant in a regional and national context. Of the 192 islands surveyed, 148 (77 %) had breeding seabirds.

Population sizes had decreased in some species (Lesser Noddy, Sooty Tern, Common (Brown) Noddy, Wedge-tailed Shearwater) and increased in others (Little Shearwater *Puffinus assimilis,* White-faced Storm-Petrel *Pelagodroma marina,* Silver Gull *Chroicocephalus novaehollandiae,* Pacific Gull *Larus pacificus*) since the last survey undertaken in 1999. Some changes in breeding numbers were attributed to improved survey technology, but others reflected true changes brought about by a range of factors including availability of tree nesting habitat and availability of food sources to opportunistic species. Shifts in breeding times among some species (e.g. Bridled Tern *Onychoprion anaethetus*) were also noted.

INTRODUCTION

The Houtman Abrolhos, located approximately 60 kilometres off the coast from Geraldton, Western Australia, are on one of the southernmost coral reef systems in the Indian Ocean. The Leeuwin Current surrounds the Houtman Abrolhos (Pearce 1997) and is the source of a unique assemblage of tropical larval fishes, corals and algae that inhabit the reef areas in association with temperate species (Hatcher 1991). The diversity and abundance of tropical and temperate marine life supports the largest population and the most species-rich assemblage of seabirds in the eastern Indian Ocean (Surman 1992; Fuller *et al*. 1994; Surman and Wooller 2003; Burbidge and Fuller 2004). The Houtman Abrolhos is also one of the most significant seabird breeding locations along Australia's coastline. Based on the most recent population estimates (Burbidge and Fuller 2004) 80 per cent of Common (Brown) Noddies *Anous stolidus*, 40 per cent of Sooty Terns *Onychoprion fuscata* and all Lesser Noddies *Anous tenuirostris melanops* found in Australia nest at the Houtman Abrolhos (see also Ross *et al*. 1995; Surman and Wooller 2000). It also contains the largest breeding colonies in the eastern Indian Ocean of Wedge-tailed Shearwaters *Ardenna pacificus*, Little Shearwaters *Puffinus assimilis*, White-faced Storm-Petrels *Pelagodroma marina* and Fairy Terns *Sternula nereis* as well as the highest numbers of breeding White-breasted Sea-Eagles *Haliaeetus leucogaster*, Eastern Ospreys *Pandion haliaetus* and Caspian Terns *Hydroprogne caspia*. The Houtman Abrolhos also hosts the northernmost breeding colonies in the Indian Ocean of Little Shearwater and White-faced Storm-Petrel.

Most reports on the status, timing of breeding and behaviour of breeding seabirds prior to 1991 were based on short (1–3 days) visits to the islands. More recently the Department of Environment and Conservation (formerly Conservation and Land Management – CALM) undertook more thorough population surveys (see Burbidge and Fuller 1989; Fuller *et al*. 1994; Burbidge and Fuller 2004). The first long-term research into seabird breeding ecology at the Houtman Abrolhos was undertaken at Pelsaert Island in the Pelsaert Group in 1991, and continued until 2001 (Surman 1992, 1997, 1998; Surman and Wooller 1995; Surman and Wooller 2000, 2003; Gaughan *et al.* 2002). More recent investigations have looked at the influence of the Leeuwin Current upon reproductive behaviour of colonial seabirds (Surman and Nicholson 2009a, b) as well as long-term cycles of mangrove use by the Lesser Noddy (Surman and Nicholson 2008).

This paper presents the results of a brief survey of the breeding seabirds and migratory waders present at the Houtman

Abrolhos in December 2006. The survey was designed to meet, wherever practicable, the methodology established by previous workers (Fuller *et al*. 1994; Burbidge and Fuller 2004) in order to compare population sizes of the major seabird colonies with studies conducted in the 1990s, and to identify any long-term changes in the location of breeding colonies. Observations from other visits to the Houtman Abrolhos by the authors are added where appropriate.

METHODS

Study site

The Houtman Abrolhos Archipelago (Figure 1) consists of three major island groups with one solitary island to the north (North Island). The Wallabi, Easter and Pelsaert (or Southern) groups are located near the edge of the continental shelf between 28°15'S and 29°00'S. The islands are classified as Class A Reserve No. 20253 under the Department of Fisheries, Western Australia.

Field visits

The Houtman Abrolhos was visited between 1 and 21 December 2006 inclusive. The survey commenced at the Pelsaert Group (Figure 1) between 1 and 10 December, proceeded to the Easter Group from 10–16 December and was completed in the Wallabi Group from 16–21 December.

A total of 192 islands, islets and rocks were surveyed during daylight hours, mostly on foot after gaining access in a plate aluminium 4.6-metre open dinghy. Two islands (North and Hummock Islands) were not included in the survey due to time and logistical constraints.

Population estimates

Breeding population sizes of seabirds were calculated using two techniques; *viz*., total island counts of active nests or burrows and estimates of populations based on nest/burrow densities and colony area on the larger islands.

It was not always practicable (nor desirable because of disturbance to breeding colonies) to locate all nests of breeding seabirds on those islands small enough to survey efficiently with aerial (count of the number of birds rising into the air upon our approach) and territory counts (count of the number of nests/adults present within a colony using binoculars). In the case of Pied Cormorants *Phalacrocorax varius* on Wooded Island we used aerial photographs taken in the year surveyed to count nest sites.

Monitoring quadrats established in 1991 by Fuller *et al*. (1994) were used to estimate the breeding populations of the Lesser Noddy on Pelsaert, Wooded and Morley Islands. New long-term monitoring quadrats were established in Wedge-tailed Shearwater colonies on Pelsaert and the West Wallabi Islands.

Nesting densities of surface and burrow-nesting species were obtained for those islands with colonies too large to count in their entirety. For example, we obtained nesting densities on Pelsaert Island for the Lesser Noddy, Common (Brown) Noddy, Sooty Tern, and Wedge-tailed Shearwater. Nest densities were obtained for different habitat types on each island within which each species nested. In particular, the Common (Brown) Noddy nests principally upon Nitre Bush *Nitraria billardierei* and

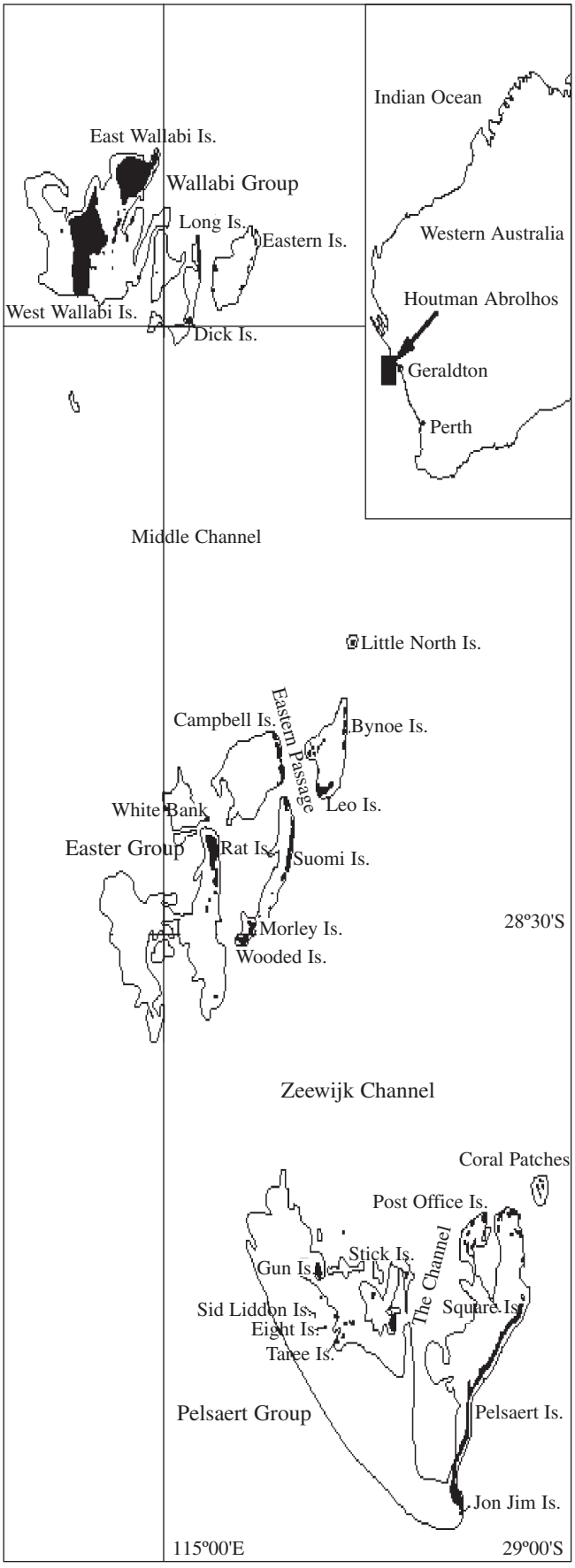

Figure 1. *Location map showing islands mentioned in the text.*

Samphire *Halosarcia halocnemoides* bushes adjacent to tidal lakes at the southernmost portion of Pelsaert Island. Because nesting density is variable between these habitats, we obtained estimates of mean densities for each major habitat type and estimated the total nesting population by applying these densities to the areas occupied by each species. We counted all nests in 49, five metres by five metres quadrats on Pelsaert Island. An estimate of the total breeding population could then be determined by extrapolating this density to the observed habitat area, with the use of the aerial photographs.

Seabird breeding habitat was mapped in the field onto recent aerial photographs (WA4064-February 1998, 1:25 000) of each island. These maps were then used to generate plots of colony areas electronically. A graduated 100 metres by 100 metres (1 ha) grid was then positioned over the aerial images in Adobe Illustrator™ to calculate total colony areas (m^2) for each seabird species on each island. Mean nesting densities for each colony on each island was then used to estimate colony size.

Burrow-nesting species

The boundaries of nesting habitat were plotted onto aerial photographs of each island in the field. In the case of larger colonies on Pelsaert and West Wallabi Islands, we established permanent transects at strategic parts of colonies that we considered to be representative of the colony as a whole. Transects were 200 metres by 5 metres and were divided into consecutive five metres by five metres quadrats. All burrows, including recently collapsed burrows (which were not included in population estimates, but gave an indication of the colony dynamics), were counted in each quadrat. Each intact burrow was inspected using an electronic burrowscope (Nicholson 2002) to determine both the stage of breeding and levels of occupancy. We also determined if burrows had a single entrance. If some had two or more entrances, these were counted as a single burrow.

For smaller islands we obtained burrow densities from a series of five metres by five metres quadrats across each new rookery area recorded. These were later used to estimate total burrow numbers, by applying observed burrow densities to differing habitat areas, depending upon island and species. This provided more accurate estimates due to the variability of burrow density based on habitat quality.

In some cases it was not possible to estimate breeding numbers due to the time of year this survey was undertaken. Little Shearwater populations may be under-estimated as in December most young had fledged, and no adults were observed attending burrows. The estimates we provide for Little Shearwaters are therefore estimates of total burrows, rather than total breeding pairs. In contrast, both White-faced Storm-Petrels and Wedge-tailed Shearwaters were present and breeding during the survey and so we were able to provide an estimate of the total numbers of burrows, and the proportion with breeding attempts.

As many mixed colonies of Little Shearwaters and White-faced Storm-Petrels were found empty, burrows not occupied by Little Shearwater or White-faced Storm-Petrels were difficult to assign to species. Whilst White-faced Storm-Petrel burrows are typically smaller, entrances to burrows are often eroded and hence enlarged to some degree. Unlike previous surveys (Fuller *et al.* 1994) we did not assign species on the basis of burrow size alone, instead we utilised burrow inspection and contents to ascertain species.

Timing of breeding

Wherever possible, we measured egg mass and dimensions to determine the timing of breeding for the larger colonial nesting species, as well as estimating the ages of any nestlings observed (Wooller and Dunlop 1980; Surman and Wooller 1995). Timing of breeding in some species varies greatly from one year to the next, reflecting marine productivity in the seas adjacent to the Houtman Abrolhos (Surman and Nicholson 2009a, b). The use of simple measurements taken at the nest allows an accurate assessment of the participation rate and timing of breeding and hence potential reproductive performance (Surman 1997, 1998). This is essential in monitoring the health of seabird populations at the Houtman Abrolhos in a highly dynamic and variable marine environment.

Disturbance to the colonies of the dense surface-nesting species such as Crested Terns *Thalasseus bergii*, Roseate Terns *Sterna dougalli*, Fairy Terns and Pied Cormorants was avoided. Colonies were not approached directly and field personnel kept out of the direct view of nesting birds, to avoid the risk of disturbing the whole colony and creating opportunities for gull predation of eggs and/or young hatchlings. In these cases, nest counts were carried out from a safe distance or from the vessel using binoculars. This method is not considered as accurate as a foot survey, however most of each colony could be observed and the well being of the colony was considered to be the priority.

Nomenclature

Wherever possible gazetted names for islands were used as per Harvey *et al*. (2001).

For the purposes of this report, the avifauna results have been separated into four main categories referred to throughout the report. These are:

- Seabirds – those birds associated with the sea and deriving most of their food from it, and typically breeding colonially.
- Raptors – those birds which capture their prey with curved talons, including the Eastern Osprey, White-bellied Sea-Eagle, Brahminy Kite *Haliastur indus* and Nankeen Kestrel *Falco cenchroides*.
- Resident Shorebirds – those birds that inhabit the intertidal zone and adjacent areas (e.g. Oystercatchers *Haematopus* spp.) and remain resident the Houtman Abrolhos throughout the year.
- Migratory Shorebirds – those birds that forage in the intertidal zone and migrate to the area from the northern hemisphere (e.g. Ruddy Turnstone *Arenaria interpres*).

Names for bird species follow that presented in Christidis and Boles (2008).

RESULTS

A total of 996 962 pairs of birds comprising three species of resident shorebird, two raptors and 14 seabirds were recorded breeding at the Houtman Abrolhos in December 2006 (Table 1). Of the 192 islands, islets and rocks surveyed, 148 (77%) contained breeding seabirds (Table 2). Appendix 1 provides a summary of the breeding seabirds for each island. In addition Appendix 2 lists those migratory shorebirds recorded during the December visit. A brief description of the results obtained for each species observed during the survey is given below.

Breeding seabirds, resident shorebirds and raptors

Red-tailed Tropicbird *Phaethon rubricauda*

We found no breeding pairs of this species on any islands, although it has bred in the past on Pelsaert Island (Storr *et al*. 1986, Burbidge and Fuller 2004). Surman (*pers. obs.*) regularly observed birds (up to 9) displaying over Pelsaert Island in November/December of each year from 1994–2001. There were four pairs breeding in 2000 along the southern and western portion of Pelsaert Island (Surman *pers. obs.*). Between 1993 and 2001, no fledgling birds survived to flying age, and bodies were often found predated, presumably by the White-breasted Sea-Eagle.

White-faced Storm-Petrel *Pelagodroma marina*

Estimated breeding total: 17 995 pairs. We recorded this species breeding on 13 islands, with significant colonies on Stick Island (5886), Morley Island (5344), Dick Island (2016), Bynoe Island (794), Long Island (612) and Suomi Island (1500). This species was regularly found occupying burrows amongst colonies of Little Shearwaters in areas where it may have been missed previously. We found no evidence of this species amongst the Wedge-tailed Shearwater rookeries examined.

Wedge-tailed Shearwater *Ardenna pacifica*

Estimated breeding total: 644 883 burrows on seven islands, although only 243 112 pairs were estimated to be breeding during the 2006/07 season (Table 3). Examination by burrowscope of the contents of 325 burrows on West Wallabi Island and Pelsaert Island indicated a breeding participation rate of 32.3 per cent in 2006 (Table 4). This is one of the lowest participation rates reported for the Houtman Abrolhos since records started in 1993 (Dunlop *et al*. 2002; Gaughan *et al*. 2002; Surman and Nicholson 2008). The Houtman Abrolhos contain the largest breeding colonies of this species in the eastern Indian Ocean (Fuller *et al*. 1994). Of interest were the remains of several birds below the communications tower on Rat Island in December 2006, and two live birds observed on

TABLE 1

Total population size (breeding pairs) and number of breeding islands for each species observed at the Houtman Abrolhos in December 2006.

Species	Number of Breeding Islands	Breeding Population Size (Pairs)
Red-tailed Tropicbird	1	0*
White-faced Storm-Petrel	13	17 995
Wedge-tailed Shearwater	7	644 883
Little Shearwater	46	60 356
Pied Cormorant	8	2234
Eastern Reef Egret	4	4
Eastern Osprey	33	42
White-bellied Sea-Eagle	18	25
Australian Pied Oystercatcher	15	18
Sooty Oystercatcher	5	5
Common (Brown) Noddy	1	121 320
Lesser Noddy	3	34 103
White Tern	1	0**
Bridled Tern	90	2274
Sooty Tern	8	105 407
Fairy Tern	13	547
Caspian Tern	22	70
Roseate Tern	19	4210
Crested Tern	10	2928
Pacific Gull	63	152
Silver Gull	25	389
Total Islands Used	148	
Total Population (pairs)		996 962

*No Red-tailed Tropicbirds were observed breeding during the 2006 season.
** A single White Tern inhabits Lesser Noddy colonies at Wooded Island.

TABLE 2

Total numbers of islands occupied by seabirds for each group at the Houtman Abrolhos.

Island Group	Number of Islands	Number of Unused Islands
Wallabi Group (incl. North)	48	8
Easter Group	68	15
Pelsaert Group (incl. Hummock)	76	21
Total	192	44

TABLE 3

The mean (+ S.E.) nesting density (nests/25 m^2) and mean estimated population sizes for Wedge-tailed Shearwater colonies at the Houtman Abrolhos during 2006 for Pelsaert Island and West Wallabi Island (see text for explanation). Population estimates were calculated based on three measures; (a) total burrows observed including those recently collapsed, (b) total intact burrows (excluding collapsed) and (c) total active burrows (burrows with a breeding attempt).

Island	Colony Area (ha)	Burrow Density			Population Size (pairs)		
		(a) Mean burrow density	(b) Mean burrow density	(c) Mean active burrows	Mean total burrows	Mean intact burrows	Mean active burrows
Pelsaert	26.02	4.67 (0.34)	4.22 (0.34)	1.22 (0.21)	48 570 (3561)	43 944 (3532)	12 700 (2177)
West Wallabi	311.36	4.8 (1.80)	4.48 (1.82)	1.59 (1.49)	610 280 (35 365)	600 939 (35 390)	230 412 (29 110)
Total					658 850	644 883	243 112

TABLE 4

The contents of burrows examined using an electronic camera (burrowscope) and the percentage containing active breeding attempts at the Houtman Abrolhos during December 2006.

	Burrow Contents						
	Unused		Used				
	Empty	Collapsed	Adult and egg	Predated egg	Adult alone	Contents unknown	Total examined
Pelsaert	80	12	30	1	2	1	126
West Wallabi	109	3	71	3	13	0	199
Total	189	15	101	4	15	1	325
Percentage (%) with breeding attempts	58.2	4.6	31.1	1.2	4.6	0.3	100

the island adjacent to the Saville Kent Centre in December 2007 (Surman *pers. obs*.). There was once a massive colony of Wedge-tailed Shearwaters on Rat Island, which was destroyed by guano digging (ceased on Rat Island in 1904), rats (present by 1840, Stokes 1846) and cats (Storr *et al*. 1986). Cats and rats were successfully eradicated by 1993 (Burbidge and Morris 2002). It is possible that Wedge-tailed Shearwaters have returned to nest on Rat Island in low numbers, but no burrows were located. Adult birds return to the region in August, lay a single egg in their burrow between 17 November and mid-December, and young hatch in early January. Adults cease returning to feed their young in April, and approximately two weeks after being deserted, the young fledge *en masse* (Surman 1998). The birds may migrate northwards; large numbers of Wedge-tailed Shearwaters have been recorded at sea north and west of the Montebello Islands, and west of Thevenard Island between May and July 2005 (Surman *pers. obs*). These may represent birds from colonies across the North West Shelf, or from regions further south (e.g. Shark Bay, Houtman Abrolhos, Rottnest Island), either overwintering in the area or passing through the region during the non-breeding period.

Little Shearwater *Puffinus assimilis*

Estimated breeding total: 60 356 burrows (the number of pairs could not be calculated as this species was not present and breeding at the time of the survey). Burrows recorded on 46 islands. Our estimates greatly increase the potential breeding population at the Houtman Abrolhos compared with those previously recorded (Fuller *et al*. 1994). We located large colonies on West Wallabi Island, as well as large mixed colonies of this species and the White-faced Storm-Petrel on several islands. We record for the first time this species on Gun Island, where Little Shearwater burrows were interspersed amongst burrows of the larger Wedge-tailed Shearwater. We also located eight burrows of this species along the western coast of Rat Island.

Pied Cormorant *Phalacrocorax varius*

Estimated breeding total: 2234 pairs on eight islands. We observed a single active colony of this species in mangroves on Wooded Island (1298 nests) where there were numerous large nestlings and juvenile birds dispersed across the lagoon. Recently used nests of this species were also recorded on the Numbered Islands in the Pelsaert Group; Eight Island (200 nests) and Sid Liddon Island (575 nests). This species continues to nest on the mangroves of Wooded Island, which are also used by the Lesser Noddy. The colony on Wooded Island has moved west along the southern margin of mangroves into areas of high density Lesser Noddy nesting. The subsequent destruction of the canopy of the mangroves is likely to reduce the suitable habitat available to the Lesser Noddy.

Eastern Reef Egret *Egretta sacra*

Estimated breeding total: less than four pairs. Breeding in this species was completed by the time of our survey in December 2006, however we recorded 59 individuals throughout the group, all of which were dark phase birds. In 2005, a nest of this species was observed on Long Island, Wallabi Group, located under a limestone overhang and just above high water (Surman *pers. obs*).

Eastern Osprey *Pandion cristatus*

Estimated breeding total: 42 pairs. We observed nests of this species on 53 islands, however only 33 of these were recently used. Islands with more than one nest were West Wallabi (4), Pelsaert (5), Suomi (2), Campbell (2) and East Wallabi (2). Most nestlings had fledged by the time of our survey in December. This species regularly utilizes nesting platforms of converted lobster pots constructed by fishers on Post Office Island, Rat Island and Little Pigeon Island.

White-bellied Sea-Eagle *Haliaeetus leucogaster*

Estimated breeding total: 25 pairs. We recorded nest sites on 25 islands of which 18 had currently active nest sites. The most significant island was West Wallabi Island, where eight active nest sites were observed. This is the major predator of fledgling and adult seabirds at the Houtman Abrolhos, consuming large numbers of Wedge-tailed Shearwaters and Little Shearwaters as well as Tammar Wallabies *Macropus eugenii* on West and East Wallabi Islands. On Pelsaert Island, two nests were situated atop the tallest of the mangrove trees in the middle of two of the Lesser Noddy colonies there; birds were regularly observed under the edges of the mangroves where they roost whilst feeding on captured Lesser Noddies. A feeding roost on a structure associated with the old guano-loading jetty on Pelsaert Island contains the remains of many Common (Brown) Noddies and Sooty Terns.

Australian Pied Oystercatcher *Haematopus longirostris*

Estimated breeding total: 18 pairs on 15 islands (Appendix 1). This species was recorded roosting on 38 islands, and its breeding population is likely significantly larger than that reported here. We recorded 68 individuals on Pelsaert Island, and 11 on East Wallabi Island. Australian Pied Oystercatchers had finished breeding and several juvenile birds were observed. In October 2005, three nests of this species were located on Long Island in the Wallabi Group.

Sooty Oystercatcher *Haematopus fuliginosus*

Estimated breeding total: five pairs on five islands (Appendix 1). This species is far scarcer than its congener, the Australian Pied Oystercatcher. A total of 12 individuals were observed, with most on Gun Island and West Wallabi Island. All individuals were of the race *fuliginosus*.

Common (Brown) Noddy *Anous stolidus*

Estimated breeding total: 121 320 pairs on Pelsaert Island. We estimated a potential breeding population based on existing nest sites of 163 980 pairs, however based on actual breeding attempts we estimate that 121 320 pairs bred in 2006/07 (Table 5). This species were incubating eggs, which were either pipped, or hatching, giving a lay date of early November. This species have a highly variable laying date, linked to food supply, which is determined by oceanographic conditions offshore (Surman and Nicholson 2009). In comparably poor food years, Common (Brown) Noddies commence laying in mid-late November, compared with early September in food rich years (Surman 1997, Surman and Wooller 2003). In January 2005, 13 nests (three with fresh eggs) constructed of seaweed and shells on a coral ridge were located on Campbell

TABLE 5

The mean (±SE) nesting density (nests/25m^2, n = 49) and mean estimated population sizes for Common (Brown) Noddy colony at the Houtman Abrolhos during 2006 (see text for explanation).

Island	Area (ha)	Nest Density			Population Size (pairs)		
		Mean total nests	Mean recent nests	Mean active nests	Mean maximum population	Mean potential 2006	Mean actual participants
Pelsaert	70 500	58.1	43.1	43	163 980 (14 140)	121 560 (13 655)	121 320 (13 681)

Island in the Easter Group. This small colony was unsuccessful. Previously, the only records of this species nesting outside of the Pelsaert Island colony, after the cessation of nesting on Rat Island at the turn of the 20th century, have been a small colony observed in 1913 on Wooded Island (Johnstone and Coate 1992), 200 nests on Wooded Island in 1999 and single empty nests recorded on Alexander Island and Little North Island in 1995 (Burbidge and Fuller 2004).

Lesser Noddy *Anous tenuirostris melanops*

Estimated breeding total: 34 103 pairs on three islands, Pelsaert, Wooded and Morley Islands (Table 6). There were significantly more empty unused nests than those that were occupied across all colonies surveyed (Table 7). The total maximum breeding population, if all intact, existing nest sites had been utilized, would be 86 000 pairs (Table 6). The decline in the Lesser Noddy population could be attributed in part to a decline in available nesting habitat, as large areas of mangroves in each colony had died off and were no longer occupied. The lateness of the season, and the low participation rates indicated that food supply was poor in this season.

There has been some significant deterioration in nesting habitat at all three Lesser Noddy colonies. On Morley Island, approximately 48 per cent of available mangrove areas had died off, and on Wooded Island approximately 31 per cent had died off leaving large areas devoid of any canopy cover, a pre-requisite for nesting in the Lesser Noddy (Surman and Wooller 1995). In contrast only 12 per cent of mangroves had died on Pelsaert Island. The die-off on Wooded Island was in part linked to the presence of the large Pied Cormorant colony there. Similar dieback was evident in the main mangroves surrounding the Lesser Noddy Lakes on Pelsaert Island. However, at this location Lesser Noddies had started to relocate to the mangroves at Big Lagoon, three kilometres north, where the canopy remains intact. Lesser Noddies were first observed returning to these mangroves in December 2005, after vacating them in 1992.

Bridled Tern *Onychoprion anaethetus*

Estimated breeding total: 2274 pairs on 90 islands. This was the most widespread of all seabird species breeding at the Houtman Abrolhos. Whilst there were no large colonies of this species, since it usually nested at a relatively low density on most islands, it inhabited all islands with suitable nesting habitat. The absence of this species on many islands during the day in December 2006 was in stark contrast to our previous observations between 1993 and 2001 (Surman *pers. obs.*). In other years, Bridled Terns returned to the islands in October, and commenced laying eggs in November (Surman 1998). By the time of our visit in December there were very few Bridled Terns in attendance, and those that were nesting had only just laid their eggs. In most years, several thousand Bridled Terns were observed overhead on Gun Island (Burbidge and Fuller 2004; Surman *pers. obs.*), but in 2006 we only counted 178 pairs. Of interest is the re-establishment of Bridled Terns on Rat Island where the rats and cats had been successfully eradicated (Burbidge and Morris 2002). We recorded 90 pairs nesting amongst the extensive limestone slab walls remaining from the guano digging days. The colony was located in the southern portion of Rat Island, principally south of the path to the airstrip. None were recorded on Rat Island between 1991–1999 (Burbidge and Fuller 2004).

Sooty Tern *Onychoprion fuscata*

Estimated breeding total: 105 407 pairs on eight islands (Table 8). Sooty Terns were incubating eggs or young chicks in December. The colony on Pelsaert Island appears to have decreased in both numbers of pairs and area occupied. The colony areas and participation rates were far lower than previously estimated. During an extended study of the breeding biology of this species at the Houtman Abrolhos, Surman (1997) recorded a mean egg lay date between 1993 and 1995 of 7 to11 October. In early January 2005, no eggs or chicks were found on Leo, Morley or Wooded Islands, although thousands of adults were present. All nests examined in December 2006 still contained eggs, and we estimated a laying date of mid-November, indicating that it was an exceptionally late and reproductively poor year for this species. This species, at least in the Easter Group, is highly dynamic, regularly shifting the location of colonies and exhibiting large population changes. On Morley Island in January 2005 we found evidence of nesting and approximately 400 birds were present, however in December 2006 there were only 40 birds present overhead and none nesting. Burbidge and Fuller (2004) reported approximately 120 000 pairs on Wooded Island in 1999; by 2006 there were only 6724 pairs. Similarly, in 1999 there were 15 000 pairs on Little North Island, but we recorded only five pairs in 2006, and there were no nests on Leo Island in 1999, but we recorded 20 096 pairs in 2006.

TABLE 6

The mean (± S.E.) nesting density (nests/20m^2) and mean estimated population sizes for Lesser Noddy colonies at the Houtman Abrolhos during 2006 (see text for explanation). All nests in each quadrat were counted and each nest assigned a status based on previous observations collected by Surman (1997). Population estimates were then calculated using the mean density for the (a) maximum total population (including unused nests), the (b) total potential for 2006 (including those nests now empty and unused) and the (c) mean actual based on observed participation (those nests with active attempts).

Island	Colony No.	Colony area (m^2)	Nest Density			Population Size (pairs)		
			Mean total nests	Mean recent nests	Mean active nests	(a) Mean maximum participants	(b) Mean potential participants	(c) Mean actual participants
Pelsaert	1	13 610	33.4	20.6	9.2	22 712	14 007	6294
			(0.8)	(0.6)	(0.3)	(2105)	(1744)	(830)
	2	11 280	41.8	37.9	24.6	23 605	21 366	13 868
			(3.6)	(3.5)	(2.6)	(2048)	(2001)	(1477)
	5	4330	15.6	14.2	9.6	3356	3193	2273
			(3.9)	(3.8)	(2.6)	(1084)	(1051)	(670)
	8	600	16	12	6	192	192	192
					Total Pelsaert Island	49 865	38 758	22 627
Wooded		7050	41.4	33.9	12.7	15 488	12 712	4758
			(7.4)	(6.3)	(2.9)	(2519)	(2162)	(1050)
Morley		7690	48.8	43.8	15.1	20 647	18 532	6718
			(7.1)	(6.4)	(2.3)	(2580)	(2355)	(1383)
Total						86 000	70 002	34 103

TABLE 7

Nest contents of all Lesser Noddy nests surveyed on Pelsaert, Wooded and Morley Islands during December 2006. Colony number refers to that given in Burbidge and Fuller (1992).

Island	Colony	Nest Contents									Total
		Empty		Occupied							
		Old	New	Egg Alone	Egg Broken	Adult Egg	Chick Alone	Adult Chick	Adult and ?	Chick dead	
Pelsaert	1	307	272	76	1	17	46	10	66	6	
	2	135	452	228	14	32	198	88	264	12	
	5	7	23	3	0	0	0	13	32	0	
Total Pelsaert Island		449	747	307	15	49	244	111	362	18	2302
Wooded		126	361	22	1	21	26	27	112	7	703
Morley		110	632	64	3	26	71	83	74	11	1074
Total		685	1740	393	19	96	341	221	548	36	4079
(%)		16.8	42.6	9.6	0.4	2.3	8.4	5.4	13.4	0.8	100

TABLE 8

The mean (± S.E. for Pelsaert Island)nesting density (nests/25 m^2) and mean estimated population sizes for Sooty Tern colonies at the Houtman Abrolhos during 2006 (see text for explanation).

Island	*n*	Colony area (m^2)	Mean nest density	Mean Population Size
Pelsaert	33	105 650	13.2 (1.6)	56 064 (6 665)
Alexander	5	13 670	17	9295
Wooded	3	8200	20.5	6724
Leo	4	24 100	19	20 096
White	3	17 200	17	11 696
Total				105 407

Fairy Tern *Sternula nereis*

Estimated breeding total: 547 pairs on 13 islands. Significant colonies were found on West Wallabi Island (162 pairs), Pelsaert Island (160 pairs) and Sandy Island (71 pairs). A few pairs of this species were often observed amongst the larger Roseate Tern colonies.

Caspian Tern *Hydroprogne caspia*

Estimated breeding total: 70 pairs on 22 islands. Caspian Terns typically nest solitarily across much of their range. However, several small colonies were found at the Houtman Abrolhos, including Leo Island (at least 13 pairs), West Wallabi Island (at least 18 pairs) and White Bank (6 pairs). At least 10 pairs nested on Pelsaert Island, mostly solitarily, although a small colony of four pairs have regularly bred near Big Lagoon in the centre of Pelsaert Island (Surman, 1998, unpublished field notes). Most birds had large runners or fledglings by the time of our visit.

Roseate Tern *Sterna dougalli*

Estimated breeding total: 4210 pairs on 19 islands. Significant colonies were found on Pelsaert Island (2004 pairs in two colonies), and Dick Island (719 pairs). Most birds were still incubating eggs or on very young chicks. This species nests on several islands in the Pelsaert Group (notably Square, Pelsaert and Jon Jim Islands), rotating their colony sites every few years. It also regularly nests during autumn. We observed nesting in April on Post Office Island in 1995, 1996 and 1997, on Newman Island in 1997, and on Long Island in May 2007 (Surman 1998 *pers. obs*.).

Crested Tern *Sterna bergii*

Estimated breeding total: 2928 pairs on ten islands. At the time of our survey Crested Terns were attending medium-sized runners, although some still incubated eggs. In the past, a large Crested Tern colony on Pelsaert Island would commence laying eggs in mid-October (Surman 1998, Gaughan *et al*. 2002), however the age of runners present during our survey suggested that eggs were laid in mid-November 2006. The largest colonies were found on Pelsaert Island (1200 pairs), Morley/Crake Islands (the colony had spread from one island to the other – 756 pairs), Long Island (190 pairs) and Bynoe Island (180 pairs). This species also nests in autumn. In March 1997 we observed a new colony established on Stick Island (Surman 1998).

Pacific Gull *Larus pacificus*

Estimated breeding total: 152 pairs breeding on 63 islands. Significant breeding islands included Pelsaert Island (39 nests), Three Island (13 nests) and Wooded Island (4 nests). A large colony of this typically solitary breeder nested approximately 100 metres north of the main Lesser Noddy mangroves on Pelsaert Island. Another relatively large colony breeds on Three Island, part of the Numbered Group. The colonies at the Houtman Abrolhos represent one of the most significant breeding sites for this species in Western Australia.

Silver Gull *Chroicocephalus novaehollandiae*

Estimated breeding total: 389 pairs on 25 islands. The largest colonies were observed on Long Island (142 nests), Pelsaert Island (43 nests), Leo Island (34 nests) and Wooded Island (33 nests). There are significant differences in the size of breeding colonies in summer and autumn. Approximately 50 pairs nest on Post Office Island during the autumn compared with only two pairs during the summer period. In May 2007 on Long Island there were at least 142 pairs of Silver Gulls attending nests, whereas in December 2006 only three nests were active. This presumably reflects increased food availability through the discard of rock lobster baits to this species during the presence of rock lobster fishers between March and June.

Non-breeding seabirds

Hutton's Shearwater *Puffinus huttoni*

This species has been included as it has been observed regularly throughout the Houtman Abrolhos between November and February since 1993 (Surman *pers. obs*.). The Houtman Abrolhos appear to be an important feeding and resting area for this species during its migration from New Zealand where it breeds on mountain slopes on the North Island (Harrow 1965). Flocks of up to 50 individuals, as well as numerous others interspersed amongst rafts of Wedge-tailed Shearwaters, were observed in The Channel (Pelsaert Group) and Eastern Passage (Easter Group). Hundreds of Hutton's Shearwaters were also observed across the North West Shelf between May and July 2005, and occasional birds amongst rafts of Wedge-tailed Shearwaters in November 2005 (Surman *pers. obs*.), perhaps confirming Warham's (1981) suggestion that this species circumnavigates Australia.

White Tern *Gygis alba.*

A single individual of this species was regularly observed amongst Lesser Noddies, adjacent to mangroves on Wooded Island during the December 2006 survey. A White Tern was also observed foraging off Pelsaert Island (30 km to the south) in January 2001. The nearest breeding colony is on Ashmore Reef (2000 km NNE) and the Cocos Islands (2500 km NW).

Non-breeding shorebirds

This survey also indicated the importance of the Houtman Abrolhos to migratory waders. 16 species of waders were identified during this survey (Appendix 2). Of the 192 islands, many were occupied by waders along shorelines, tidal flats or tidal ponds. There were significant flocks feeding on the tidal flats along the eastern shores of West Wallabi Island, along the sandy beaches of both East and West Wallabi Islands, and along Pelsaert Island.

DISCUSSION

This survey presents updated population estimates for the breeding seabirds of the Houtman Abrolhos. One hundred and ninety two (192) islands, islets and rocks were surveyed over 21 days in December 2006. Of these, 148 islands (77%) contained breeding seabirds.

This survey showed significant differences in both the distribution and abundance of breeding seabirds when compared with previous surveys, the last comprehensive survey having taken place in 1999 (Fuller *et al*. 1994; Burbidge and Fuller 2004). These differences may be attributed to survey methodology or stochastic and environmental variables influencing populations. However, this survey was undertaken at the same time as previous surveys, and utilised comparable methodology. One major difference that we had made to the methodology was that we differentiated between those nests that were unused in the current season, recorded contents of nests wherever possible to provide an indication of reproductive stage and effort, and inspected burrow contents of burrow nesting species with a non-intrusive electronic camera. This difference could certainly improve the accuracy of active breeding participation estimates for each of the burrow-nesting species.

Previous research has demonstrated the strong influence of the El Niño Southern Oscillation (ENSO) upon the strength of the Leeuwin Current, and as a result, both the timing of breeding and reproductive output of seabirds at the Houtman Abrolhos (Surman 1997; Surman and Nicholson 2009a, b). Although data from the last few years are yet to be analysed, it appears that there has been a gradual shift in the breeding window of colonial seabirds at the Houtman Abrolhos to later in the year. The species most affected included all the offshore or pelagic foraging tropical species (i.e., Lesser Noddy, Common (Brown) Noddy, Sooty Tern and Wedge-tailed Shearwater). Inshore foragers, notably the Pacific Gull, Silver Gull, Caspian Tern and to a lesser extent Crested Tern, Roseate Tern and Fairy Tern, appeared to not be affected to the same degree.

Declining arboreal nesting populations

Our results and previous observations (Burbidge and Fuller 2004) indicate that there are fewer Lesser Noddies breeding at the Houtman Abrolhos than previously. Table 9 shows the total number of active nests for each of the three islands that Lesser Noddies have nested at since 1989. Numbers have declined from an estimated 77 360 pairs in 1989 to just 34 103 pairs in 2006. The current breeding population represents 42 per cent of the total in 1989 on Pelsaert Island, 41 per cent of the 1989 total on Morley Island and 54 per cent of the maximal total (recorded in 1995) on Wooded Island. The carrying capacity, as indicated by the total number of nest sites (occupied and unoccupied) recorded in 2006, was 86 000 pairs (Table 6). However, considerable areas of the Wooded and Morley Island mangroves are no longer utilised, so the potential carrying capacity would be higher given a full recovery of the mangroves. Burbidge and Fuller's (2004) estimate of 77 360 breeding pairs in 1989 represents 90 per cent of the current estimated carrying capacity. We are unable to determine if the population of this threatened species is in decline, as the data suggests, or if there is a large component of the adult population not currently participating in breeding. Further analysis of a long-term dataset of marked Lesser Noddies may indicate the participation rate in each year at the individual level.

We speculate that a combination of below average rainfall and over nitrification from guano has contributed to the dieback of mangroves at the Houtman Abrolhos. Mangrove dieback was found to be cyclical, and associated with the use of mangroves by the Lesser Noddy. In response, Lesser Noddies have adapted by relocating their nesting sites once mangrove areas become defoliated. It may take up to 13 years for mangroves to recover from dieback (Surman and Nicholson 2008).

Fluctuating burrow-nesting populations or improved counting methods?

In the last survey of burrow-nesting species, Fuller *et al.* (1994) recorded Little Shearwaters on 26 islands, with a total population of 30 555 pairs, White-faced Storm-Petrels on 14 islands with 4227 pairs and Wedge-tailed Shearwaters on 12 islands with 1 117 816 pairs. Our estimates doubled the number of Little Shearwaters and the number of islands on which they bred, and tripled the number of White-faced Storm-Petrels. In contrast we estimated that there were only 644 883 Wedge-tailed Shearwater burrows in total, of which only 243 112 were occupied during the 2006/07 season.

We found that Little Shearwaters shared extensive areas of the Wedge-tailed Shearwater colony on West Wallabi Island, and that White-faced Storm-Petrels readily bred in what previously may have been presumed to have been Little Shearwater burrows. We frequently found White-faced Storm-Petrels on islands where previously only Little Shearwaters were reported. For example, we found that there were large numbers of White-faced Storm-Petrels on Morley Island, where previously only Little Shearwaters had been recorded breeding, and a colony amongst Little Shearwaters on Suomi Island and Long Island. We surmise that one of the reasons for the differences in our estimates for burrow nesting species, when compared with previous surveys, is that burrow size was used as an indicator of species, whereas we were able to check burrow contents with a burrowscope. Erosion of burrow entrances may enlarge burrows, resulting in misidentification. Another contributing factor, which we found due to our ability to check burrow contents, was that the later breeding White-faced Storm-Petrel occupied burrows that may have been previously used in some instances by Little Shearwaters. Our findings greatly increased the importance of the Houtman Abrolhos for burrow nesting species. Both Little Shearwaters and White-faced Storm-Petrels breed here at the northern limit of their range.

TABLE 9

Estimated number of Lesser Noddy nests surveyed on Pelsaert, Wooded and Morley Islands between 1989 and 2006. Data from 1989-1999 adapted from Burbidge and Fuller (2004).

Island	Year							
	1989	1991	1993	1995	1996	1997	1999	2006
Pelsaert	54 110	41 760	34 870	38 700	39 500	42 355	40 700	22 627
Wooded	6875	5345	6325	8890	7920	6074	14 485	4758
Morley	16 375	11 750	7665	9600	8930	12 300	12 800	6718
Total	77 360	58 855	48 860	57 190	56 350	60 729	67 985	34 103

Declining ground nesting populations

Our estimate for the Sooty Tern population of 105 407 pairs was a quarter of the estimate provided in Burbidge and Fuller (2004). In 1999, they estimated that 80 000 pairs bred on Alexander Island, and 120 000 pairs on Wooded Island. These estimates were far in excess of our counts for these two islands, based on the density of nests, and greater than our estimate for the principal colony on Pelsaert Island in 2006. Our estimated colony area on Pelsaert Island was 10.5 hectares compared with 12.5 hectares (Burbidge *et al.* 2004), indicating that estimated nesting density was far lower on Pelsaert Island in 2006 than that recorded previously. We found that for Wooded Island to support the estimated population in 1999 of 120 000 pairs, all dry areas of the island (including beach areas) would have had to be occupied at a nesting density twice that recorded in 2006. Consequently we believe that caution should be used when comparing these two surveys, as it greatly enhances the decline in the population density of Sooty Terns, perhaps artificially. It does appear, however, that the 2006 season was comparatively poor for this species, as indeed it was for the Wedge-tailed Shearwater and Bridled Tern. Regardless, the number of breeding pairs of this species is less than previously recorded, and this was probably the result of oceanographic influences affecting food supply for this pelagic forager (as discussed previously).

We estimated a total Common (Brown) Noddy breeding population on Pelsaert Island, to which this species is confined, of 121 320 pairs. This was approximately 70 per cent of the estimate provided by Burbidge and Fuller (2004). Interestingly, we report a mean density of 43.1 nests per 25 square metres, compared with that recorded previously of 24.8 nests per 25 square metres. It appears that in 2006, Common (Brown) Noddies occupied less of the southern portion of Pelsaert Island, but nested in higher densities. Observations between 1993 and 2000 of marked individuals and nest sites showed Common (Brown) Noddies on Pelsaert Island to exhibit strong site fidelity (Surman 1997 *pers. obs.*). Birds constructed new nests, or repaired previous season's nests directly on top of the previous nesting site. These observations indicate that there is likely to have been little movement in Common (Brown) Noddies between nest sites or nesting habitat, reflecting the stability of the habitat. Thus, whilst there were marked differences in the density of nests between the two habitats, the differences in population estimates from one year to the next most likely reflect the levels of participation in each year. In 2006 Common (Brown) Noddies had a high participation rate, with many birds incubating eggs or young chicks. In recent years Common (Brown) Noddies have colonised Lancelin Island, where approximately 1000 pairs breed each year (Dunlop 2005). It has been hypothesised that these individuals were originally from the Pelsaert Island colony (Dunlop 2005).

Few Bridled Terns were present during our survey in December 2006. We noticed a gradual increase in the numbers of Bridled Terns present at colonies during the day as we progressed northwards. By the time of our survey of the Wallabi Group there were more representative numbers of Bridled Terns present. However, the low numbers of Bridled Terns attending colonies, and the delayed onset of breeding indicated that the 2006 breeding season was a late one, and thus potentially reproductively poor for this species.

Increased opportunistic species and impacts

The influence upon seabird populations by user groups at the Houtman Abrolhos is largely through increased provisioning of food for those species able to take advantage of food scraps or bait discards. Large numbers of Silver and Pacific Gulls follow lobster boats, scavenging discarded baits. Pied Cormorants are also able to take advantage of baits, and are occasionally caught in lobster pots (Anon. 2005) Our census shows a 155 per cent increase in the population of Pied Cormorants at the Houtman Abrolhos since 1991 (Table 10). It is evident that the increase in cormorant numbers has impacted upon the mangrove-nesting habitat of the Lesser Noddy on Wooded Island, where there has been an increase from 700 pairs in 1991 to 1298 pairs in 2006. The presence of Pied Cormorant nests built upon the mangrove destroys habitat through physical (trampling and collapsing during nest making) and chemical means (from the action of guano upon foliage), and makes these areas unavailable to the Lesser Noddy which nests only in these trees at the Houtman Abrolhos. Our most recent survey in 2007 found that the cormorants had further extended their colony into mangrove areas not used previously, resulting in the displacement of Lesser Noddies to other areas (Surman and Nicholson 2008). If this trend continues it could have drastic repercussions for Lesser Noddies at the Houtman Abrolhos.

TABLE 10

Total population size of the potential increaser species, the Silver Gull, Pacific Gull and Pied Cormorant at the Houtman Abrolhos between 1991 to 2006 (data from 1991-1999 from Burbidge and Fuller 2004).

Species	Year			% Increase
	1991-93	1999	2006	
Pied Cormorant	876	561	2234	155
Pacific Gull	43	60	138	220
Silver Gull	153	32	356	132

This survey also concentrated on locating nests of both gull species that breed at the Houtman Abrolhos. Both species weave large, conspicuous nests from either seaweeds (Pacific Gull) or grasses and *Spinifex longifolius* (Silver Gull). We located 152 recently used nests of the Pacific Gull during this survey on 63 islands, more than double the number located by the previous survey (Burbidge and Fuller 2004). Similarly, we found 389 Silver Gull nests on 25 islands, compared with only 32 on 14 islands during the 1999 survey, an increase of 1115 per cent since 1999, and an increase of 154 per cent since the 1991 survey (Burbidge and Fuller 2004). Many of the Silver Gull nests located appeared to have been utilised during the autumn/winter period, however our estimates may still under represent the autumn breeding populations of this species. There is little doubt that the Silver Gull population is increasing at the Houtman Abrolhos. Importantly, the majority of nesting in the Silver Gull takes place during the rock lobster fishing season rather than during the spring/summer period when their natural prey, including the eggs and chicks of seabirds, is more abundant. The abundance of readily accessible discarded fish baits has likely supplementary fed Silver Gulls and led to an increase in the autumn breeding population.

Pacific Gull numbers may be increasing as a result of interactions with the local rock lobster fishers. However, Pacific Gulls continue to nest exclusively during spring, and thus must locate food to raise young at a time when there are no fishers at the Houtman Abrolhos. The presence of extra food sources during the lobster fishing season however, may increase the fitness of breeding birds prior to commencement of nesting. The population increase, when compared with the 1999 survey (Burbidge and Fuller 2004), may be explained by recruitment from other areas, or due to favourable foraging conditions resulting in an increase in recruitment of adult birds from the local population. We believe that we have slightly underestimated the numbers of pairs of Pacific Gulls, most notably on East and West Wallabi Islands. The increase in the Pacific Gull population at the Houtman Abrolhos is particularly significant in the context of diminishing populations elsewhere due to coastal development and competition with the Kelp Gull *Larus dominicanus* (Anon. 2006).

CONCLUSIONS

This survey is the first comprehensive seabird survey of the Houtman Abrolhos since 1999 (Burbidge and Fuller 2004), and more significantly, the first for burrow nesting species since 1993 (Fuller *et al.* 1994). While improvements in technological methods will ultimately lead to more accurate estimates of breeding, such change can cause discrepancies when comparing recent estimates with historical records. Therefore caution is required when interpreting changes to estimates of breeding populations of burrow-nesting species. Nevertheless, for those species where consistent techniques have been used, changes in breeding seabird population sizes are an important means of tracking local and global environmental events.

Our work reinforces the importance of the Houtman Abrolhos as a major seabird breeding location in both an Australian and global context. Coupled with a reduction in seabird breeding numbers since the first surveys in the 1990s, the low-lying nature of the islands makes them particularly susceptible to the predicted rises in sea levels. The continuation of this work on a regular basis is highly desirable so that the ongoing management and protection of seabirds at one of Australia's most significant seabird breeding colonies can remain effective and well informed.

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• Pelsaert Island from the air looking north. Large significant colonies of Common (Brown) Noddies, Sooty Terns and Wedge-tailed Shearwaters nest at this southern end. Large colonies of Lesser Noddies are located in mangroves in the middle of this island.

APPENDIX 1

The total numbers (pairs) of breeding seabirds, resident shorebirds and raptors recorded during an island wide survey at the Houtman Abrolhos in December 2006.

Species	Group	Island	Pairs
Red-tailed Tropicbird	Pelsaert	Pelsaert	0*
White-faced Storm-Petrel	Wallabi	Beacon	1386
		Eastern	59
		Dakin	57
		Dick	2016
		First Sister	20
		Long	612
		Seal	121
	Easter	Bynoe	794
		Dry	100
		Little North	100
		Morley	5344
		Suomi	1500
	Pelsaert	Stick	5886
		TOTAL	**17 995**
Wedge-tailed Shearwater	Wallabi	West Wallabi	610 280
	Easter	Rat	?
	Pelsaert	Davis	<80
		Gun	4255
		Middle	1037
		Murray	1800
		Pelsaert	12 789
		Sweet	>50
		TOTAL	**630 291**
Little Shearwater	Wallabi	Eastern	262
		Akerstrom	>100
		Alcatraz	8
		Beacon	2046
		Dakin	209
		First Sister	53
		First Sister (2nd Islet N)	18
		Hall Is.	14
		Little Pigeon	50
		Long	376
		Marinula	16
		Pigeon	50
		Saville-Kent	288
		Seal	181
		Shag Rock	20
		Tattler	50
		Traitors	2
		Traitors (Islet 1)	6
		West Wallabi	38 343
	Easter	Alexander	102
		Bynoe	844
		Campbell	363
		Crake	100
		Dry	50
		Gilbert	>17
		Helms	10
		Keru	>9
		Leo	3247
		Little North	20
		Morley Islet	<10
		Morley	6804
		Rat	8
		Sandy	54
		Shearwater	<30
		Shearwater (islet to S)	10
Little Shearwater	Easter	Suomi	1343
		White Bank	5
		White Island	476
		Wooded	2976
	Pelsaert	Davis	<10
		Gun	1736
		Iris Refuge	>6
		Middle	>1
		One	6
		Pelsaert	26
		Three	1
		TOTAL	**60 356**
Pied Cormorant	Wallabi	Hall Is.	9*
		Traitors (Islet 2)	2
	Easter	Wooded	1298
	Pelsaert	Eight	200
		One	<50
		Seven	<50
		Sid Liddon	575*
		Sweet	>50
		TOTAL	**2234**
Eastern Reef Egret	Wallabi	Long	1
	Easter	Serventy	1?
	Pelsaert	Coronation	1
		Pelsaert	1
		TOTAL	**4**
Eastern Osprey	Wallabi	Dick	1
		East Wallabi	2
		Little Pigeon	1
		Long	1
		Pigeon	1
		Third Sister	1
		Traitors (Islet 2)	1
		Traitors (Islet 5)	1
		West Wallabi	4
	Easter	Bushby	1
		Bynoe 2 (2nd islet W)	1
		Campbell	2
		Crake	1
		Gilbert Islet 4	1
		Helms (islet 2 to SW)	1
		Joe Smith	1
		Leo	1
		Rat	1
		Suomi	1
	Pelsaert	Arthur	1
		Coral Patch 5	1
		Coronation	1
		Gun (1st islet S)	1
		Jackson Islet 1	1
		Jon Jim	1
		Lagoon	1
		Murray	1
		Newman	1
		Pelsaert	5
		Sid Liddon	1
		Square	1
		Stick	1
	Pelsaert	Three	1
		TOTAL	**42**

APPENDIX 1 (Continued)

Species	Group	Island	Pairs
White-bellied Sea-Eagle	Wallabi	Akerstrom	1
		Dick	1
		East Wallabi	1
		First Sister	1
		First Sister (3rd islet N)	1
		Long	1
		Oystercacher	1
		Pelican	1
		Seagull	1
		Tattler	1
		West Wallabi	8
	Easter	Alexander	1
		Leo (islet to N)	1
		Sandy	1
		Serventy	1
		Suomi	1
	Pelsaert	Davis	1
		Pelsaert	1
		TOTAL	**25**
Australian Pied Oystercatcher	Wallabi	Dick	0
		East Wallabi	1
		Little Pigeon	1
		Long	1
		Marinula	0
		West Wallabi	1
		Dakin	0
		Seal	1
		Third Sister	0
		Traitors	0
		Turnstone	1
	Easter	Bynoe	0
		Campbell	1
		Keru	0
		Leo	0
		Little North	0
		Morley	0
		Rat	1
		Shearwater (islet to S)	0
		Suomi	1
		White Bank	0
		White Island	1
	Pelsaert	Basile	0
		Burnett	1
		Coronation	0
		Eight	0
		Fairbridge	0
		Foale	0
		Jackson	0
		Little Jackson	0
		Murray	0
		Newman	0
		Pelsaert	4
		Post Office	1
		Post Office Islet	0
		Square	1
		Three	0
		Uncle Margie (Mangrove)	1
		TOTAL	**18**
Sooty Oystercatcher	Wallabi	West Wallabi	1
	Easter	Bynoe	1
		Keru	0
		Leo	0
		Morley Islet	1
		Serventy	0
Sooty Oystercatcher	Easter	White Island	0
		Wooded	1
	Pelsaert	Gun	1
		Jon Jim	0
		Middle	0
		Two	0
		TOTAL	**5**
Common (Brown) Noddy	Pelsaert	Pelsaert	121 320
		TOTAL	**121 320**
Lesser Noddy	Easter	Morley	6718
		Wooded	4758
	Pelsaert	Pelsaert	22 627
		TOTAL	**34 103**
White Tern	Easter	Wooded	0
		TOTAL	**0**
Bridled Tern	Wallabi	Akerstrom	3
		Alcatraz	4
		Beacon	103
		Dakin	15
		Dick	100
		Eastern	23
		Little Pigeon	>12
		Long	152
		Marinula	14
		Marinula (islet to NE)	12
		Pelican	18
		Pigeon	31
		Saville-Kent	>11
		Seal	6
		Tattler	1
		Traitors	3
		Traitors (Islet 5)	3
		Wann	3
	Easter	Alexander	>21
		Alexander 1 (Islet to N)	2
		Alexander 2 (Islet to S)	8
		Bynoe	77
		Bynoe 1 (1st islet to W)	2
		Bynoe 2 (2nd islet to W)	4
		Bynoe 3 (3rd islet to W)	3
		Campbell	81
		Crake	5
		Dry	5
		Gibson Islet 1 (large to N)	4
		Gilbert	74
		Gilbert Islet 2	1
		Gilbert Islet 3	1
		Gilbert Islet 4	1
		Helms	13
		Helms (islet 1 to SW)	9
		Helms (islet 2 to SW)	3
		Joe Smith	4
		Keru	61
		Landscope	2
		Leo	64
		Leo (islet to east E)	5
		Leo (islet to north)	6
		Little North	243
		Little Rat	28
		Little Roma	5
		Little Stokes	3
		Morley Islet	4
		Morley	>1

APPENDIX 1 (Continued)

Species	Group	Island	Pairs
Bridled Tern	Easter	Nitraria	5
		Rat	90
		Roma	>3
		Serventy	139
		Shearwater (islet to S)	4
		Stokes	53
		Suomi	219
		Tapani	4
		Tapani Islet SW	1
		White Island	46
		White Islet	2
		Wooded	20
	Pelsaert	Arthur	15
		Basile	4
		Burnett	5
		Burton	5
		Coral Patch 5	8
		Coronation	>5
		Coronation (1st islet NW)	4
		Davis	<8
		Eight	>6
		Fairbridge	>7
		Gaze	3
		Gregory	12
		Gun	178
		Iris Refuge	>4
		Jackson	>26
		Jackson Islet 5	>2
		Lagoon	>6
		Little Jackson	>7
		Newman	>17
		One	13
		Pelsaert	21
		Post Office	4
		Rotondella	1
		Rotondella (2nd islet to S)	3
		Square	>19
		Stick	>40
		Three	5
		Two	3
		Uncle Margie (Mangrove)	3
		TOTAL	**2274**
Sooty Tern	Wallabi	Dick	5
	Easter	Alexander	10 717
		Leo	20 096
		Little North	5
		Serventy	<100
		White Island	11 696
		Wooded	6724
	Pelsaert	Pelsaert	56 064
		TOTAL	**105 407**
Fairy Tern	Wallabi	Dick	29
		East Wallabi	1
		Long	12
		West Wallabi	162
	Easter	Gilbert	19
		Helms	12
		Leo	47
		Sandy	71
		Shearwater	8
	Pelsaert	Coronation	15
		Lagoon	7
		Newman	4
		Pelsaert	160
		TOTAL	**547**
Caspian Tern	Wallabi	Dick	1
		Long	1
		Seal	1
		Turnstone	1
		West Wallabi	22
	Easter	Alexander 2 (Islet to S)	1
		Bushby	1
		Leo	14
		Morley	1
		Rat	1
		Serventy	1
		Tapani	1
		White Bank	6
		Wooded	1
	Pelsaert	Burnett	1
		Eight	1
		Gun	1
		Lagoon	1
		Murray	1
		Pelsaert	10
		Sid Liddon	1
		Three	1
		TOTAL	**70**
Roseate Tern	Wallabi	Dick	719
		Far	30
		Long	65
		West Wallabi	10
	Easter	Gilbert	190
		Helms	41
		Keru	>21
		Leo	>1
		Little Stokes	250
		Sandy	10
		Shearwater	4
		White Island	45
		Wooded	>179
	Pelsaert	Burnett	119
		Coronation	19
		Fairbridge	250
		Little Jackson	250
		Pelsaert	2004
		Robertson	3
		TOTAL	**4210**
Crested Tern	Wallabi	Long	190
		Wann	106
	Easter	Bynoe	180
		Crake	486
		Morley	>270
		Wooded	>10
	Pelsaert	Coronation	186
		Gun	260
		Pelsaert	1200
		Sid Liddon	40
		TOTAL	**2928**
Pacific Gull	Wallabi	Eastern	1
		Beacon	1
		Dakin	1
		Dick	3
		East Wallabi	2
		Little Pigeon	1
		Long	2
		Marinula	3
		Marinula (islet to NE)	3
		Oystercatcher	1

APPENDIX 1 (Continued)

Species	Group	Island	Pairs
Pacific Gull	Wallabi	Pigeon	1
		Saville-Kent	1
		Seal Islet N (G Island)	1
		Third Sister	1
		Traitors	1
		Turnstone	1
		West Wallabi	1
	Easter	Bynoe	2
		Campbell	3
		Gibson	4
		Gibson Islet 1 (large to N)	1
		Gilbert	2
		Helms (islet 2 to SW)	1
		Joe Smith	2
		Landscope	2
		Leo	6
		Leo (islet to east)	1
		Little North	1
		Little Stokes	1
		Morley Islet	1
		Morley	3
		Rat	6
		Serventy	1
		Shearwater (islet to S)	1
		Stokes	2
		Suomi	4
		White Bank	1
		Wooded	4
	Pelsaert	Arthur	1
		Basile	1
		Burnett	1
		Burnett (1st islet N)	1
		Coronation	1
		Diver (off W Post)	1
		Eight	1
		Fairbridge	2
		Gaze islet 2	1
		Gun	1
		Jackson	1
		Jon Jim	1
		Little Jackson	2
Pacific Gull	Pelsaert	Middle	1
		Murray	1
		Newman	1
		Pelsaert	39
		Sandy	1
		Sid Liddon	1
		Square	1
		Stick	1
		Sweet	1
		Three	13
		Travia (2nd islet SE)	1
		Uncle Margie (Mangrove)	2
		TOTAL	**152**
Silver Gull	Wallabi	Long	142
	Easter	Alexander	>4
		Bynoe	1
		Dry	1
		Gilbert	10
		Keru	1
		Leo	34
		Rat	6
		Serventy	10
		Shearwater	1
		Stokes	4
		Wooded	35
		Coronation	14
		Eight	>3
		Fairbridge	2
		Gun	>1
		Jackson Islet 5	1
		Lagoon	2
		Little Jackson	2
		Newman	12
		One	2
		Pelsaert	56
		Post Office	50
		Rotondella	1
		Sid Liddon	1
		Sweet	>9
		Three	1
		TOTAL	**389**

APPENDIX 2

Migratory shorebirds observed during the December 2006 survey of the Houtman Abrolhos.

Species	Group	Island	Pairs
Grey Plover	Wallabi	West Wallabi	1
Pluvialis squatarola	Easter	Keru	1
		Morley	2
	Pelsaert	Pelsaert	5
Red-capped Plover	Wallabi	Akerstrom	4
Charadrius ruficapillus		Oystercatcher	2
		Seagull	3
		Seal	2
		East Wallabi	78
		Long	6
		Shag Rock	2
		Third Sister	2
		West Wallabi	165
	Easter	Alexander	1
		Bynoe	1
Red-capped Plover	Easter	Campbell	3
Charadrius ruficapillus		Dry	2
		Gilbert	1
		Leo	3
		Morley	1
		Rat	9
		Sandy	3
		Stokes	4
		Suomi	7
		White Island	4
	Pelsaert	Pelsaert	18
		Gun	4
		Stick	1
Lesser Sand Plover	Wallabi	West Wallabi	1
C. mongolus	Pelsaert	Pelsaert	7

APPENDIX 2 (Continued)

Species	Group	Island	Pairs
Greater Sand Plover	Wallabi	East Wallabi	16
C. leschenaultii		West Wallabi	14
	Easter	Campbell	1
		Dry	1
		Morley	1
		Rat	1
	Pelsaert	Post Office	2
		Gun	1
		Murray	12
Bar-tailed Godwit	Wallabi	East Wallabi	49
Limosa lapponica		West Wallabi	47
	Easter	Bynoe	2
		Campbell	12
		Morley	4
		Suomi	1
	Pelsaert	Pelsaert	26
Whimbrel	Wallabi	Long	1
Numenius phaeopus	Easter	Gilbert	1
		Rat	1
	Pelsaert	Newman	1
Eastern Curlew	Pelsaert	Post Office	1
N. madagascariensis			
Common Sandpiper	Wallabi	Oystercatcher	1
Actitis hypoleucos	Pelsaert	Pelsaert	2
Grey-tailed Tattler	Wallabi	Eastern	1
Tringa brevipes		Akerstrom	1
		East Wallabi	3
		Long	9
		Turnstone	1
		West Wallabi	6
	Easter	Bynoe	1
		Little Rat	1
		Morley	12
		Rat	1
		Stokes	1
		Suomi	1
	Pelsaert	Burnett	1
		Gun	2
		Middle	1
		Murray	36
		Pelsaert	1
		Post Office	5
		Uncle Margie (Mangrove)	1
Common Greenshank	Wallabi	Akerstrom	1
T. nebularia		Marinula	1
		Oystercatcher	1
		West Wallabi	6
	Easter	Bynoe	1
		Rat	5
	Pelsaert	Pelsaert	1
		Post Office	1
Ruddy Turnstone	Wallabi	Beacon	20
Arenaria interpres		Dakin	5
		Eastern	5
		East Wallabi	77
		Little Pigeon	3
		Long	14
		Seagull	4
		Seal	3
		Seal Islet N (G Island)	1
		Shag Rock	1
		Turnstone	8
		West Wallabi	138
Ruddy Turnstone	Easter	Alexander	9
Arenaria interpres		Bynoe	10
		Bynoe 1 (1st islet to W)	1
		Bynoe 3 (3rd islet to W)	1
		Campbell	13
		Disappearing	9
		Dry	3
		Gilbert	2
		Helms	4
Ruddy Turnstone	Easter	Keru	1
Arenaria interpres		Landscope	3
		Leo	4
		Little North	10
		Morley	27
		Rat	14
		Serventy	1
		Serventy (Islet 4)	1
		Shearwater (islet to S)	1
		Stokes	15
		Suomi	25
		Tapani	3
		White Island	1
		Wooded	1
	Pelsaert	Burton	2
		Coral Patch 3	6
		Eight	7
		Gaze	3
		Gun	3
		Lagoon	1
		Middle	3
		Murray	16
		Newman	5
		Pelsaert	207
		Post Office	19
		Robertson	1
		Seven	2
		Stick	7
		Sweet	>10
		Travia	1
		Two	1
		Uncle Margie (Mangrove)	4
Great Knot	Pelsaert	Pelsaert	20
Calidris tenuirostris			
Sanderling	Wallabi	East Wallabi	15
C. alba		West Wallabi	5
	Easter	Disappearing	9
		Rat	3
Red-necked Stint	Wallabi	Akerstrom	1
C. ruficollis		East Wallabi	75
		Seagull	1
		Turnstone	2
		West Wallabi	254
	Easter	Campbell	3
		Disappearing	1
		Rat	4
		Stokes	2
		Wooded	1
	Pelsaert	Gun	1
		Middle	2
		Pelsaert	19
Sharp-tailed Sandpiper	Wallabi	West Wallabi	2
C. acuminata			
Curlew Sandpiper	Wallabi	Akerstrom	1
C. ferruginea		West Wallabi	3