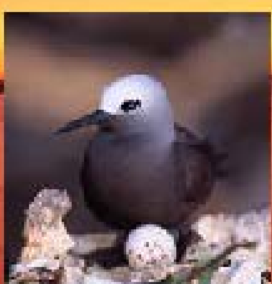
Trends in Population and Habitat Status in the Threatened Lesser Noddy *Anous tenuirostris melanops* at the Houtman Abrolhos

Final Report

Halfmoon Biosciences
July 2009



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Executive Summary

An extensive survey of the habitat use and population trends of the threatened Lesser Noddy *Anous tenuirostris melanops* was undertaken at the Houtman Abrolhos in December 2008.

Transects established in 1991 by CALM were revisited and surveyed in their entirety and population estimates obtained. The conditions of mangrove areas were assessed for dieback and destruction caused by the use of mangrove habitat for nesting by the Pied Cormorant *Phalacrocorax varius* and the Lesser Noddy *Anous tenuirostris melanops*.

On Pelsaert Island an extensive search for banded Lesser Noddies was undertaken both in marked colony areas and areas adjacent. Recaptured birds were recorded and an assessment of longevity, habitat use, and site fidelity was undertaken.

On all three breeding islands significant areas of mangrove dieback were observed at some colony locations. This was most evident on Morley Island where 39.3 % of mangrove areas had now senesced. However, some recovery in mangrove cover was evident at most sites. On Wooded Island, a colony of Pied Cormorants had moved from the main area of mangrove to an area not utilised by the Lesser Noddy.

The numbers of nesting Lesser Noddies had increased significantly between 2007 and 2008 with a rise from 30 355 pairs to 47 906 pairs. Most of the increase in breeding numbers could be attributed to the colony on Wooded Island (from 3 216 pairs in 2007 to 7 985 pairs in 2008) and Colony 5 at Pelsaert Island (from 2 135 pairs in 2007 to 7 476 pairs in 2008).

On Pelsaert Island the recent (2005) re-colonisation by the Lesser Noddy of a northern series of mangrove areas continued, with increased activity and breeding pairs at Colonies 3, 4, 5, 6 and 8. The density of nest sites found along transects at colony 5 had increased from 7.1 to 19.9 active nest sites per $20m^2$ over the past 12 months.

Lesser Noddies at the Houtman Abrolhos remain under threat from the potential impacts of sealevel change. Currently, the population of Lesser Noddies remains in a long term decline. On average, data from 2001-2008 (compared to data collected between 1991-2000) indicate that fewer are breeding, they are breeding much later than expected and they are producing fewer young. The impacts of predicted sealevel change upon the Lesser Noddy and its nesting habitat are discussed.

1 Introduction

The Houtman Abrolhos is the most significant seabird nesting area in the Eastern Indian Ocean, with 15 species contributing to over 1 million pairs breeding on 148 islands in the archipelago (Surman and Nicholson 2007)

Of these, the Lesser Noddy is of particular significance. It is listed under the EPBC as a threatened species in the vulnerable category. In the last fully quantitative survey undertaken (2006), a total of 34,103 pairs of Lesser Noddies were breeding on three islands, each island distinguished by extensive stands of the Grey Mangrove *Avicennia marina* (Surman and Nicholson 2007). This represented a fall of 49.8% from an estimated 67,985 pairs recorded during a survey undertaken in 1999 (Burbidge and Fuller 2004).

As Lesser Noddies and their cogener the Black Noddy (*Anous minutus*) have evolved from cliff nesting relatives (Surman and Wooller 2000), throughout their range they will only nest on cliff edges (e.g. Black Noddies Anous minutes on Ascension Island, Ashmole 1962, Cullen and Ashmole 1963) or in trees with substantial canopies (i.e. *Pisonia grandis* trees in the GBR, Dale *et al*. 1984). At the Houtman Abrolhos, the eastern Indian Ocean subspecies *Anous tenuirostris melanops* principally nests within forked branches of the Grey Mangrove, and shows preference for areas under the canopy (Surman 1997). A small colony of 25-40 pairs was observed nesting along the vertical edge of a large (3m) nitre bush (*Nitraria billardierei*) at the southern end of Pelsaert in 1995, however only 6 pairs of Lesser Noddies were breeding at this site in 2007.

As the Grey Mangrove is the most significant canopy forming tree throughout the Houtman Abrolhos, they are essential to the continued conservation of the Lesser Noddy. Recently, mangrove dieback and defoliation has led to the desertion of some Lesser Noddy nests along regularly monitored sites. Observations of wider scale mangrove dieback at the Houtman Abrolhos and the continued deterioration of these areas has led to the current survey.

Interestingly, previous visitors to the Houtman Abrolhos had already identified one cause of mangrove dieback, as Alexander's (1922) quote from a 1913 visit to Wooded Island clearly illustrates:

"..the accumulation of the guano round the roots of the mangroves is rapidly killing the trees, and it is unlikely that the birds would continue to nest on the boughs of the dead trees. It is to be hoped that a change to another island may lead to an increase in their numbers, otherwise I fear they must be regarded as the last remnant of a dwindling race."

In the Dry Tortugas it was found that mangroves were succumbing to both erosion and increased nutrient loads from roosting pelicans (Doyle *et al.* 2002). With sea levels predicted to rise by 9-88cm by the turn of the next century (Walsh *et al*. 2002), current mangrove growing conditions are likely to change dramatically at the Houtman Abrolhos.

Several questions could be posed:

- Is the recent dieback a result of the activity of Lesser Noddies in the mangroves?
- Is the dieback linked to ENSO?
- Do other stands of mangroves not used by noddies exhibit the same patterns over time?
- Has dieback in mangroves occurred in the past and what can this tell us about the implications for this threatened species?

The principal objectives of this project are:

- To intensively map all Lesser Noddy colonies in the Pelsaert and Easter Groups of the Houtman Abrolhos, to obtain accurate population estimates and information about nesting and habitat preferences. Nest status data will also be used to establish timing of breeding for each island. This data will be compared with historical data and will provide a measure for future change, so that any reduction in breeding numbers (against background variation) or changes in habitat condition can be identified and managed.

- To analyze 16 years of historical individual Lesser Noddy banding/recapture and marked nest occupancy data collected in the Pelsaert Island colony, so that changes in breeding participation and habitat can be compared with background stochastic events (such as ENSO years) and provide a predictive indicator for future monitoring and management.

- To make this data available as an assessment and management tool to the managers of the Houtman Abrolhos (Department of Environment and Conservation, Department of Fisheries, AIMAC), with the intention that it can be used for ongoing annual monitoring.

2 Methods

2.1 General Methods

Visits to the Houtman Abrolhos were undertaken between 13 December 2008 - 2 January 2009. Transport from Geraldton was via the surveyed charter vessel *Southern Lady II* and the DoF vessel *McLaughlan,* and between base camps and study islands a 4.6m centre consul runabout powered by a 4-stroke petrol engine was used.

2.2 Transect maintenance

The transect lines originally put in place by DEC (then Conservation and Land Management) staff were all replaced with new 50kg breaking strain nylon. The existing lines had disintegrated and snapped in some portions, so the new lines were placed to ensure repeatability of the survey areas. Fence droppers at the start and end of each transect, as well as 5m interval markers along each line were also added. The current nylon transects should last for a further 15 years.

2.2 Habitat mapping and assessment

Lesser Noddies are generally site-faithful and nest only in extensive stands of Grey Mangrove (*Avicennia marina*) on Pelsaert, Wooded and Morley Islands. There are numerous islands in the Houtman Abrolhos with stands of the Grey Mangrove that are not utilised, and the reasons why some sites are preferred to others are not known. In the past Lesser Noddies have been observed nesting in different areas of Grey Mangrove on Pelsaert Island, which were not used in the previous season. This shift of breeding birds may have been from an old area of mangrove which had died off (possibly as a result of increased nutrient loads), or it could have been due to an increase in the Lesser Noddy population causing prospecting breeders to colonize a new site. In order to better understand Lesser Noddy habitat preferences, all mangrove habitats were mapped onto current aerial photographs in the Pelsaert and Easter Groups of the Houtman Abrolhos. The boundaries of nesting areas of colonies were marked by “ground truthing” (the process of positioning colony boundaries onto aerial photos from the ground) and GPS plotting the nesting areas onto the photographs.

Those areas currently utilised (in the 2008 season) were identified and recorded on aerial maps. To complement existing Department of Land Administration images, a single light aircraft flight was utilised to obtain low-level aerial photographs using a 35mm Digital SLR. Areas of mangrove die-off/dieback were plotted. The boundaries of breeding areas were mapped onto 1:25000 colour aerial photographs, and then digitised and plotted using Adobe Illustrator.

Total mangrove habitat, as well as total colony area (in m^2) were estimated from known scale aerial photographs by overlaying in Adobe Illustrator with a scaled grid. Areas of senescing/dead mangrove trees were also plotted.

2.3 Historical analysis of aerial imagery

During analysis of the 2007 data, digital historical aerial images were obtained from the Western Australian Land Information Authority (Landgate). The images obtained covered the main mangrove areas known to be utilised by the Lesser Noddy; on

Pelsaert Island, Wooded Island and Morley Island (Figures 1 & 2). Aerial imagery was also obtained for larger stands of mangroves not used by Lesser Noddies, on islands utilised by the Rock-lobster fishing industry. The Images obtained from Landgate are listed below.

Historical references to those areas occupied by breeding Lesser Noddies were mapped onto the digitised images obtained from Landgate and time-series figures showing temporal and spatial shifts in colony size and location are presented in the Appendix. These were supplemented with more recent aerial photography undertaken in 2007 and 2008.

Images were imported into Adobe Photoshop, where they were colour adjusted, cropped and enhanced to allow for comparison between successive years. For each colony area for each year the total mangrove habitat was estimated by plotting a known scale grid over the images. Adjustments were then made for areas that were covered by tidal ponds, and estimates of those areas with dieback-affected mangroves were also made.

The total available nesting habitat (in m^2) and the total area of dieback were then plotted in Excel for each study island as well as for control islands.

Table 1: List of digital imagery obtained from Landgate for analysis of mangrove habitat.

Project No.	Film No.	Run	Frame
C60	WA885	2	5033
		3	5036
		4	5044
		4	5087
780265	WA1742	-	5203
		3	5239
		3	5241
810112	WA2048	6	5091
		7	5082
		8	5123
		9	5110
		10	5109
		11	5125
		11	5128
		12	5134
870079.03	WA2551	1	5089
		1	5092
		2	5056
		2	5096
		3	5100
		3	5101
		4	5084
		5	5123

2.3 Lesser Noddy population census and nest status

Previous researchers from the Department of Conservation (WA) established semi-permanent monitoring transects through cross-sections of the Grey Mangrove on Pelsaert, Morley and Wooded Islands, the three nesting sites of the Lesser Noddy. Nest counts took place on five occasions between 1986 and 1999 (Burbidge and Fuller 1989, Fuller *et al*. 1994, Burbidge and Fuller 2004). Since 1991, a cumulative study area of 527 permanently marked nests of the Lesser Noddy on Pelsaert Island has been monitored (Surman 1992, Surman 1997, Surman and Wooller 2003). Approximately 247 of these nest sites were monitored in the 2008 season.

An estimate of the Lesser Noddy breeding population size was made utilising the methods established by Burbidge and Fuller (1989), with adjustments for the status of nests and occupancy levels as discussed below. Quantifying the status of nests was established by Surman (1997) in order to better assess the state of breeding in the Lesser Noddy, and differentiates those nests that contain existing, old nesting material from previous seasons, from those that are under construction or ready for egg laying.

A total of ten transects on Pelsaert Island, three transects on Morley Island and five transects on Wooded Island were surveyed (Figures 1 & 2). All nests 2m each side of a central nylon line were counted and assigned a status based upon the level of decay or refurbishment of the existing nest site. Each transect was broken down into continuous 5m long sections, with the result that each survey quadrat covered $20m^2$. Each transect commenced at one edge of the mangal and bisected a section to the opposite edge, usually orientated in a west to east direction.

The total number of Lesser Noddy nests was estimated by multiplying the mean density of nests for each colony and extrapolating this to the total area occupied in that colony.

All Lesser Noddy nests recorded were assigned a status based upon the following criteria;

- Old Material – existing nest containing material from previous nesting seasons
- Sargo – Nests recently added to with fresh brown algae (*Cystophora* sp.)
- Ulva – Nests recently added to with sargassum and lined with *Ulva lactuca*
- Egg – Nests containing an egg.
- Chick – Nests containing a chick.

Lesser Noddies build large nests, which may be used for many years. In previous years, those nests most likely to be used to lay an egg were relined with *Ulva lactuca* just prior to laying. The proportion of nests surveyed containing *U. lactuca* or fresh brown algaes (*Cystophora sp*./sargassum) provides a useful indicator of pre-laying activity, and a predictor of the proportion of those nests likely to contain eggs at a later stage in the breeding cycle.

Figure 1: (a) Lesser Noddy defending nest site prior to relining with fresh material. (b) Lesser Noddy on nest recently relined with *Ulva lactuca* and fresh sargassum, (c) Lesser Noddy with egg showing accumulation of guano around edges of nest indicating recent occupancy. (d) Densely population region of Colony 2, Pelsaert Island in mangroves recovering from dieback (note resprouting foliage).

2.4 Historical Analysis of seasonal variation in the Lesser Noddy population and the estimation of an indicator of incipient change

In addition to the nest census data described above, unpublished data was also analysed from intensive research on the Lesser Noddy at the Pelsaert Island colony. As part of a post-graduate (and later post-doctoral) research project, nesting and individual data from the Lesser Noddy colony (referred to by Burbidge and Fuller 1989 as Colony 2 at the Lesser Noddy Lakes) was collected between1991 and 2006 (Surman 1992, Surman 1997, Surman and Wooller 2003, Surman and Nicholson 2007). Data on occupancy rates (the numbers of birds known to breed), timing of breeding, nest site fidelity and reproductive performance (the number of eggs that give rise to a fledged young) were collected. Recapture information of previously banded birds was also recorded. In addition, a graph showing the status of all monitored nests since 1993 was created to show the proportion of nests used or lost in each season. This data will provide a historical context for seasonal changes in the Lesser Noddy population and their habitat usage, upon which this project can estimate an indicator of population change (which will allow for environmental stochastic variation).

Lesser Noddies have shown short-term and long-term responses to variations in the strength of the Leeuwin Current, and indirectly to the El Nino Southern Oscillation (ENSO). Two indicators of strength of flow of the Leeuwin Current are the sea levels at Fremantle, Western Australia, and the Southern Oscillation Index (supplied by the National tidal Facility and the Bureau of Meteorology). For the historical context of this project these stochastic factors will be plotted against Lesser Noddy population size, reproductive performance and timing of breeding, over an 18 year time series.

Figure 2: A colour-banded Lesser Noddy at Colony 2, Lesser Noddy Lakes, Pelsaert Island. The colour combination is unique and facilitates identification of individuals without the need for recapture.

2.7 Timing of breeding

Laying chronology was determined using lay dates of known age eggs and the laying dates of other eggs were estimated by backdating, using egg water loss techniques (Wooller and Dunlop 1980, Surman and Wooller 1995). Eggs known to be re-laid were excluded from calculations of the mean date of laying for each species. Chick age was estimated from growth curves described in Surman (1997).

Backdating to determine the lay date of each egg was carried out using the following calculation (After Surman and Wooller 1995):

$$V = L.B^2$$

$$D = M/V$$

$$\text{Fresh Egg Mass} = 0.529\ (V) + 0.183$$

$$\text{Egg Age} = (D-0.538)/-0.002$$

Where M = Egg Mass, V = Volume, D = Density, L = Maximal egg length and B = maximal egg breadth.

2.8 Historical Analysis

Data supplied from the National Tidal Facility and the Bureau of Meteorology was used to plot sea level and the Southern Oscillation Index (SOI) against population estimates and reproductive parameters such as timing of breeding and breeding success.

Figure 3: Transect (red lines) locations for Pelsaert Island, showing Big Lagoon (top) and Lesser Noddy Lakes (bottom) in 2008. The yellow line represents the area of permanently marked nest sites monitored since 1991.

Figure 4: Transect locations (red lines) for Morely Island (top) and Wooded Island (bottom) in December 2008. Note the location of a portion of the Sooty Tern colony (blue line) along the margins of the mangroves on Wooded Isla
Remnant nests from the 2007 Pied Cormorant colony can also be seen.

3 Results and Discussion

3.1 Timing of breeding

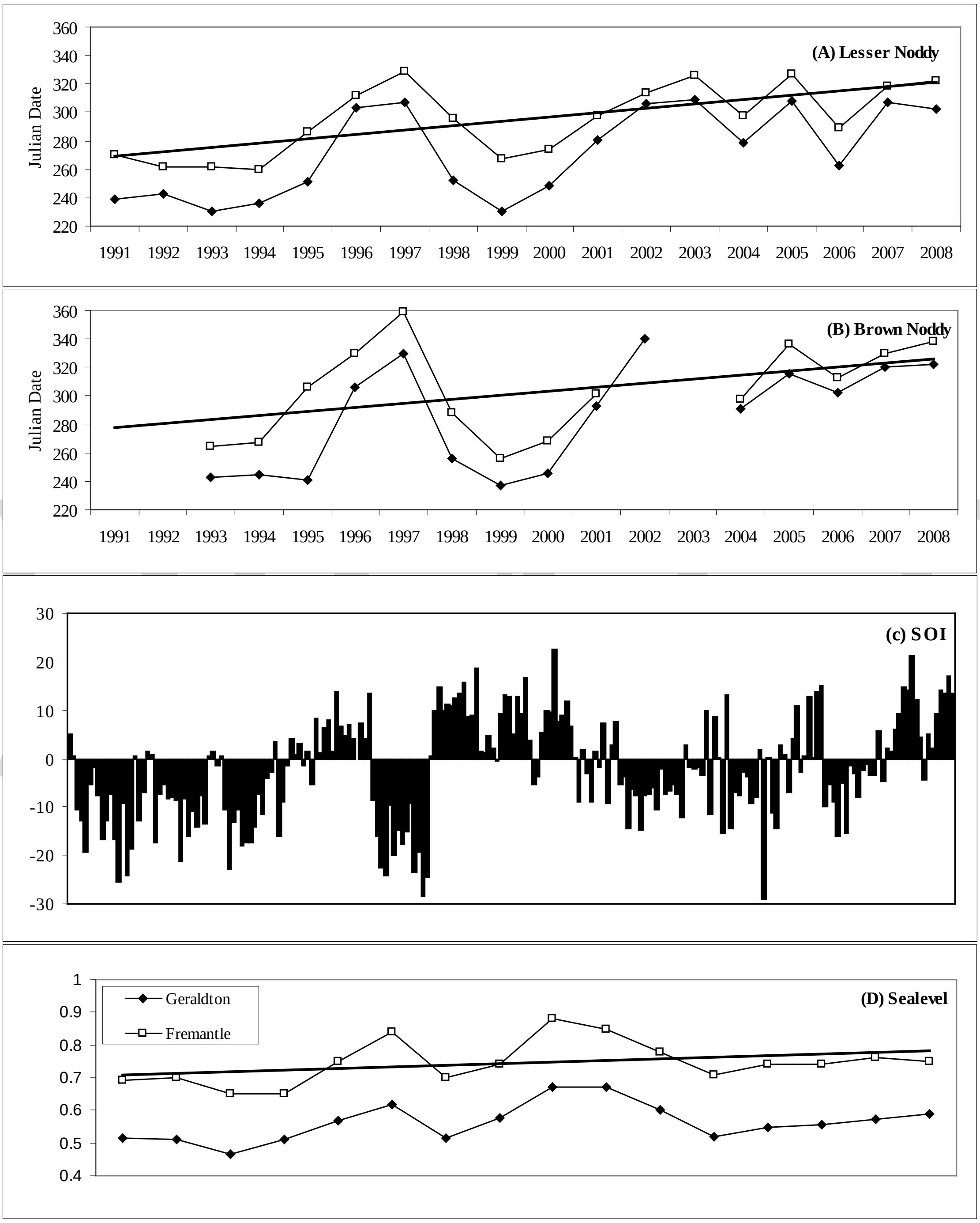
Lesser Noddies had commenced nesting relatively late during the 2008/09 breeding season, with the date of he first egg being estimated as 28 October, and the mean lay date occurring on 17 November 2008.

Figure 5 shows the date of first eggs and the mean lay date for Lesser Noddies compared to that for the cogener, the Brown Noddy at Pelsaert Island between 1991 and 2008. Later breeding coincided with stronger ENSO (low SOI values) events and lower sealevels. Nesting in both the Lesser and Brown Noddy was delayed significantly during the 1996/97 and 1997/98 austral summers with mean lay dates 65d later (Lesser Noddy) and 98d later (Brown Noddy) than in the preceding years. This was not significantly related to Fremantle sealevels between 1991-1998 (F= 3.55, df=6, p=0.11), however the mean lay date for both the Lesser and Brown Noddy was correlated to the SST between January and March (1991-1998) of the breeding year (R^2=0.67, F=12.18, P=0.012, R^2=0.74, F= 11.73, P=0.026 respectively). These species returned to early breeding during the1999/00 and 2000/01 seasons, which coincided with the SOI becoming positive once again. In years when breeding was delayed until November, there was a shorter period between the first egg laid and the mean lay date for both Lesser and Brown Noddies.

The two tern species both experienced a delayed commencement of nesting in the latter period (2001-2008) of this study (Figure 5). The data suggest that the commencement of breeding in these species had become later over the past 18 years. Interestingly, late breeding now occurs even during non-ENSO periods.

Between 1991 and 2000, the mean date of first egg in Lesser and Brown Noddies was 10 September and 19 September respectively. Between 2001-2008, this had been delayed to a mean first egg date of 19 October and 30 October respectively. This was significantly later than the earlier period for both species (Lesser t=-3.23, df=15, p=0.006; Brown t=-2.50, df=11, p=0.03). The mean lay date had also increased by 29 and 24 days in Lesser and Brown Noddies respectively, which was significantly later for the Lesser Noddy (t=-2.76, df=15, p=0.01), but not the Brown Noddy (t=-1.32, df=8, p=0.21) (Table 1).

Figure 5. Timing of breeding (Julian Date, where 27 October = 300) as represented by the date of first egg (closed diamonds) and mean lay date (open squares) in the Lesser Noddy (A) and Brown Noddy (B) with the trend line for the mean lay date for Lesser and Brown Noddies. The Southern Oscillation Index for the same period is presented below (C) and the sealevels at Geraldton and Fremantle in (D).

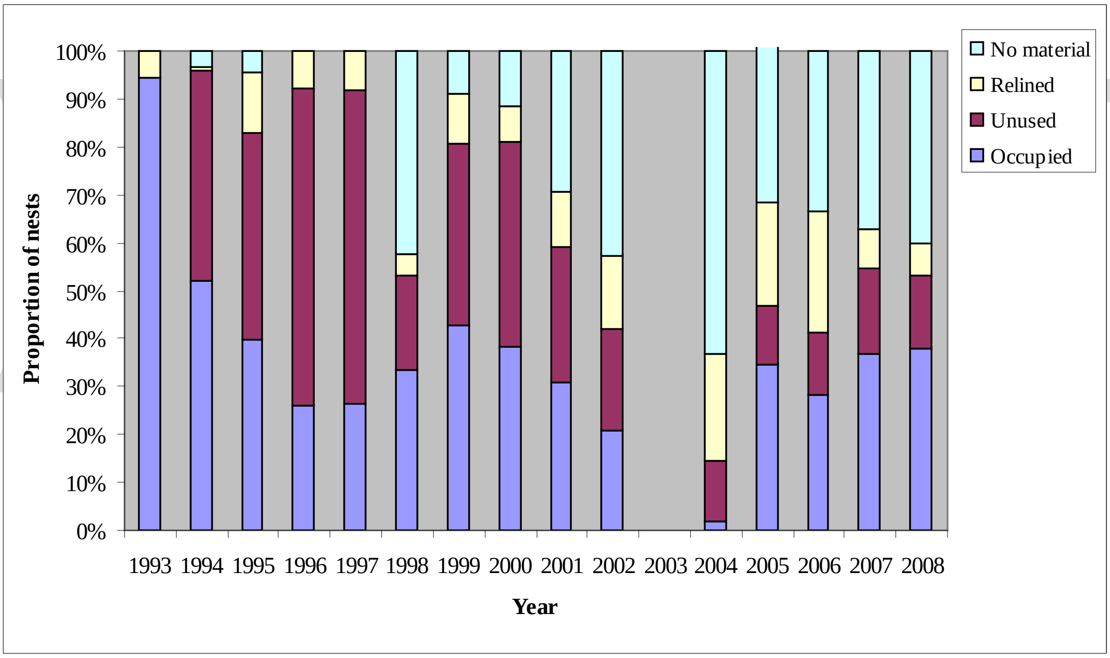


3.4 Lesser Noddy Nest Status.

An analysis of 16 years of data following individually marked nest sites at the Lesser Noddy Lakes revealed several key indicators related to the observed decline in mangrove health at this site.

Post 1996, there was a substantial increase in the proportion of nests located that remained unused. This proportion gradually declined to the present 2008/09 season, at the same time that the proportion of marked sites with no nesting material increased. This indicates longer term deterioration of previous nesting sites after birds had abandoned the area, either due to disturbance or exposure caused by a decline in cover. Once nests are not maintained the nesting material hardens, erodes and eventually is blown off the branch. The status of nest sites remained relatively stable between the 2007/08 and 2008/09 seasons.

Figure 6: The proportion of nests located along permanently marked sites that were occupied, relined, unused or had no nesting material on Pelsaert Island Houtman Abrolhos between 1993-2007.



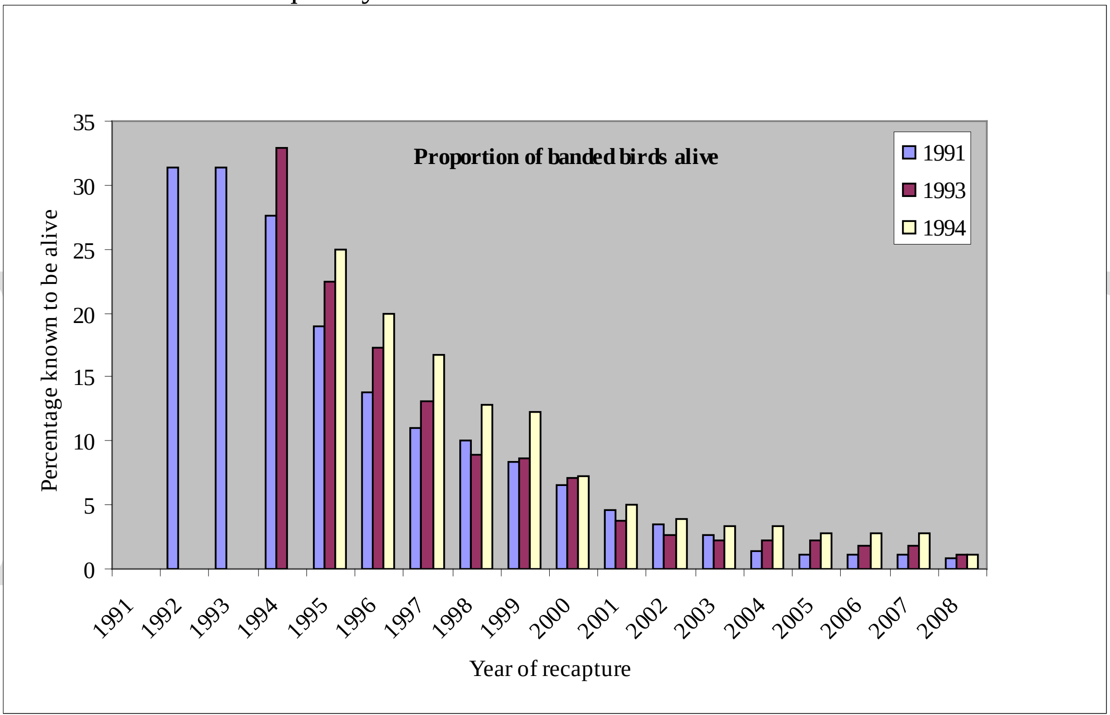
3.5 Banding Recaptures

A concerted effort was made to recapture as many previously banded individual Lesser Noddies as possible in the time available. Two techniques were utilised, firstly hand capture, either with a small hand net or by hand, or using digital photography to photograph bands on legs to be read at a later date. The latter was most useful when encountering trap-shy individuals.

A total of 383 Lesser Noddies were examined for bands in December 2008 and January 2009 at the main colonies (Colonies 1, 2 and 5) on Pelsaert Island. Of these, there were 48 recaptures and 4 banded individuals that evaded recapture. All recaptured birds were then remarked with new colour bands as per the ABBBS schema.

A comprehensive review of the 18 year banding database is summarised in Table 2. The three earliest consistent banding years (1991, 1993 and 1994) were then assessed to determine the numbers of birds banded in those years that were known to be alive in each subsequent year. Figure 7 shows that in 2007 only 4 (1%) of the 370 individuals marked in 1991 were observed breeding in 2007, all of a minimum age of 19 years. By the 2008/09 season we only located two adults banded in 1991. A summary of the total numbers of Lesser Noddies banded at the monitoring site at the Lesser Noddy lakes (Colony 2) on Pelsaert Island is given in Table 2.

Figure 7: The proportion of birds banded in 1991, 1993 and 1994 that were known to be alive in each subsequent year between 1991-2008.



		Year																	
		91	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**
No. of newly marked birds in each year		370	36	267	180	96	15	37	51	161	150	0	0	0	0	0	1	22	9
No. of recaptured birds banded in year still alive in subsequent years.	**1991**	370	116	116	102	70	51	41	37	31	24	17	13	10	5	4	4	4	3
	1993			267	88	60	46	35	24	23	19	10	7	6	6	6	5	5	3
	1994				180	45	36	30	23	22	13	9	7	6	6	5	5	5	2

Table 2: The numbers of Lesser Noddies banded in each year and the numbers known to be still alive in subsequent years at the Lesser Noddy Lakes (Colony 2) monitoring site on Pelsaert Island.

3.6 Change in Mangrove Habitat

Aerial images were obtained for most mangrove areas from 1964-2006, which enabled a comparison of mangrove habitat to be made between years (Surman and Nicholson 2008). Additional aerial images were taken during the 2008/09 season and useable mangrove habitat was plotted onto these to continue the time series.

3.6.1 Pelsaert Group

Figures 8-11 below show the total habitat available for Lesser Noddy nest sites as well as the total areas affected by die-off / dieback. The figures indicate that for the two large Lesser Noddy colonies situated at the Lesser Noddy Lakes (Colony 1 & 2), available nesting habitat peaked between1978-1987. In contrast, the large area of mangrove at the Big Lagoon (Colony 5) had only recently reached maximal foliar cover in 2007 and had maintained this in 2008, at the same time that the two Lesser Noddy Lake mangroves had declined to their lowest available habitat levels since 1964.

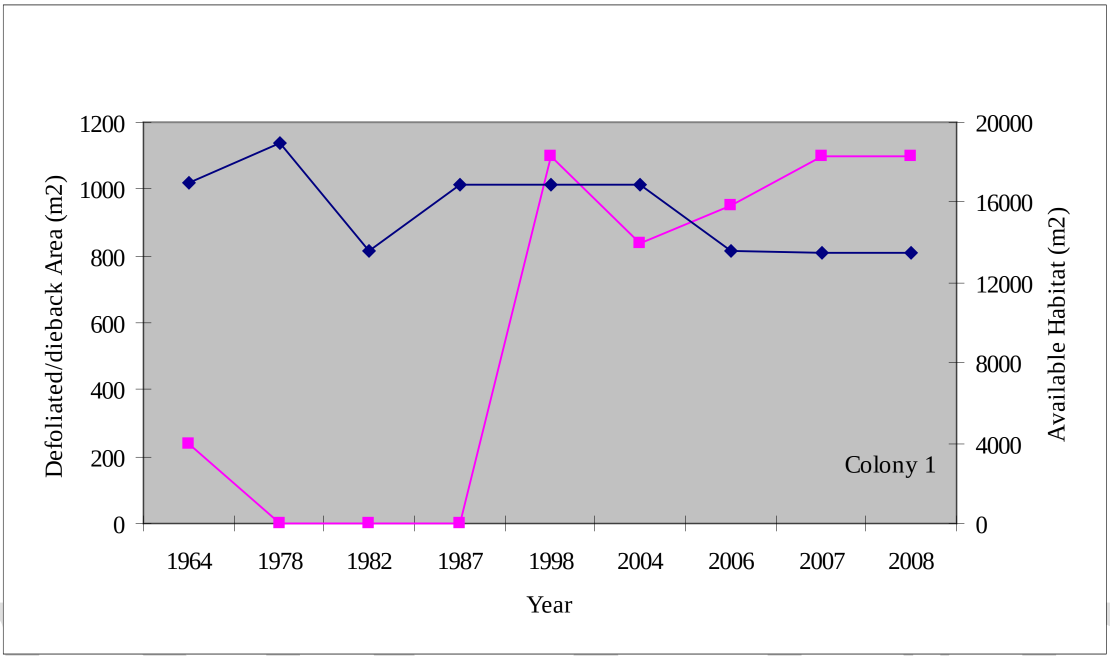
3.6.2 Easter Group

The pattern observed at the Easter Group was similar to that exhibited by the Colonies 1 and 2 on Pelsaert Island. Both Wooded and Morley Islands showed relatively stable available habitat for Lesser Noddies until a peak in 1998. On Wooded Island, available habitat declined by 31% from 8840m^2 to 6060 m^2 between 1998 and 2007. Morley Island exhibited the most severe reduction in habitat due to mangrove dieback, declining by 48% since 1998, from 12 170m^2 of available habitat to 6280m^2 in 2007.

However, more recently we estimate that the available habitat on Wooded Island has increased; defoliated areas including those occupied by the large Pied Cormorant colony had declined from 19.5% in 2007 to 10.7% in 2008. This was largely due to the shift of the Pied Cormorant colony away from the main mangrove areas rather than any mangrove recovery. On Morley Island we did record a slight increase in available habitat, and it appears that the die off recorded previously (Surman and Nicholson 2008) has reached its peak. Approximately 46% of mangrove areas were dead in 2007 compared with 39.3% in the 2008/09 seasons.

About half of the decline in available habitat on Wooded Island was accounted for by the presence of a large Pied Cormorant colony which had shifted from more eastern regions of the mangrove to the south and western portions of the mangrove. In 2007, we counted 969 Pied Cormorant nests and in 2008 1 200 nests. This population size has fluctuated by up to 50% over the past 50 years when compared with population estimates of 650-700 pairs in 1945 (Serventy 1945), 500-800 nests in 1983 (Johnstone 1983) and 450 pairs in 1999 (Burbidge and Fuller 2004).

Figure 8: The estimated area (m^2) of total available nesting habitat (black line, RHS) and total areas defoliated or undergoing dieback (pink line, LHS) for the two main colonies of Lesser Noddies at the Lesser Noddy Lake area on Pelsaert Island between 1964-2008.



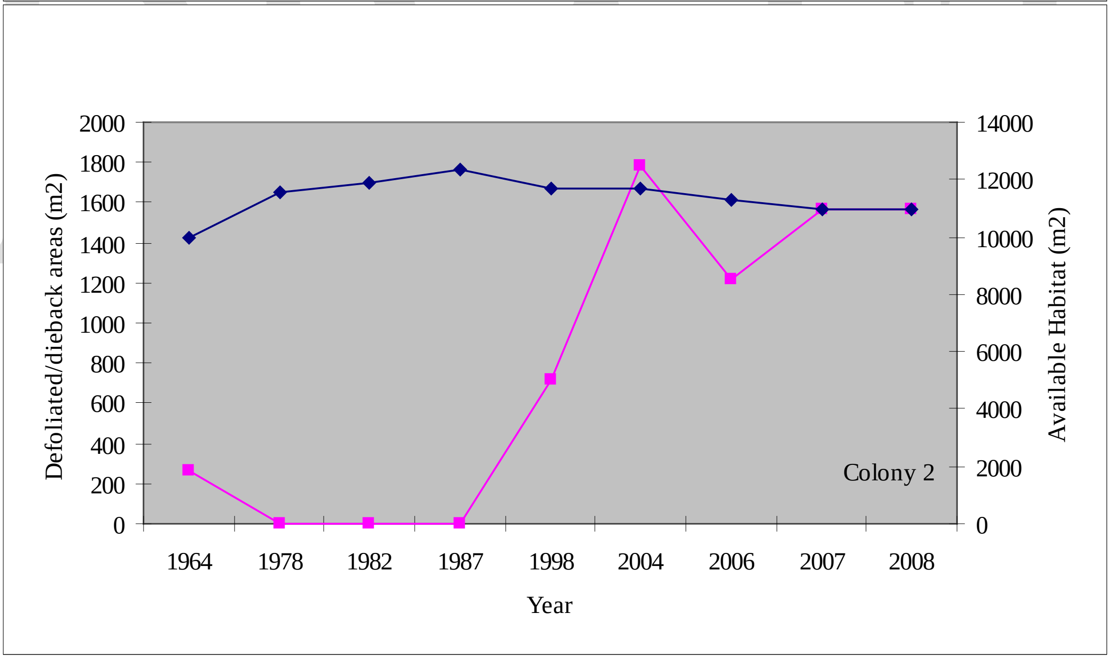


Figure 9: The estimated area (m^2) of total available nesting habitat (black line, RHS) and total areas defoliated or undergoing dieback (pink line, LHS) for the main colonies of Lesser Noddies at the Big Lagoon area on Pelsaert Island between 1964-2008. Colony 5 is the major nesting area at this location.

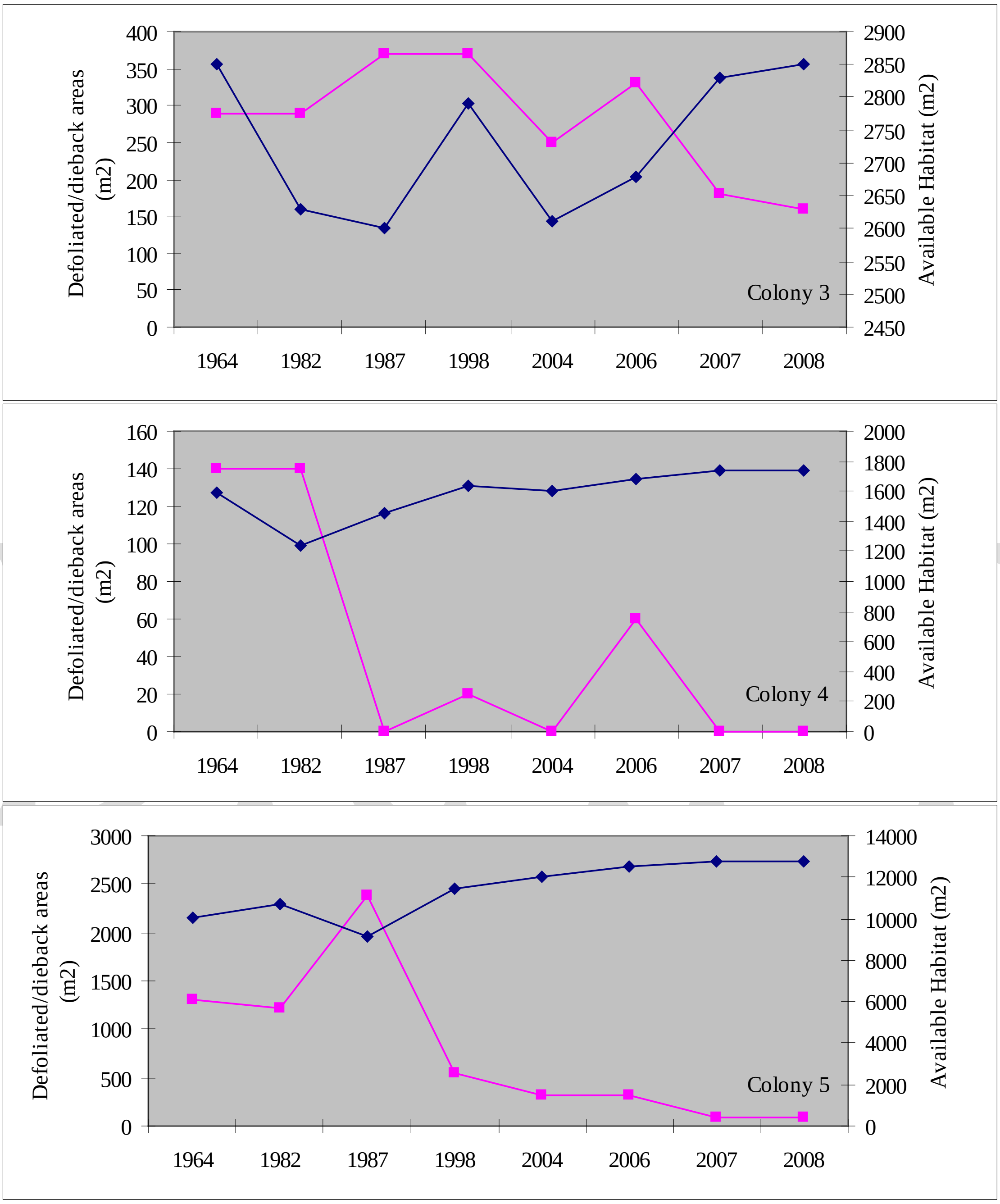
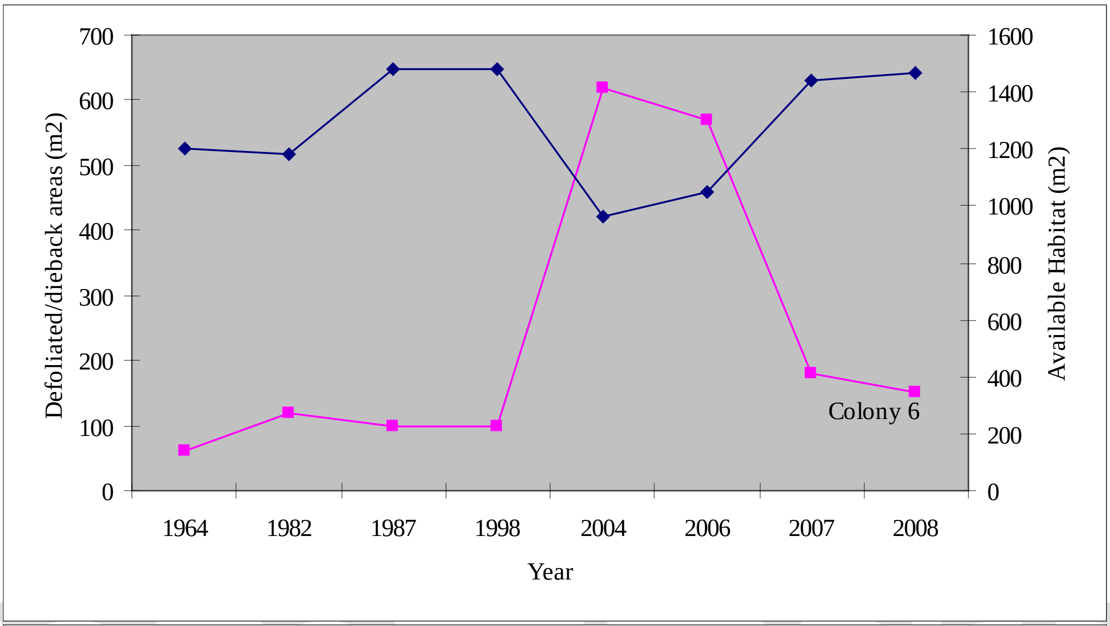


Figure 10: The estimated area (m^2) of total available nesting habitat (black line, RHS) and total areas defoliated or undergoing dieback (pink line, LHS) for the main areas of mangal situated north of the Big Lagoon area on Pelsaert Island between 1964-2008. Colony 8 is the major nesting area in this area.



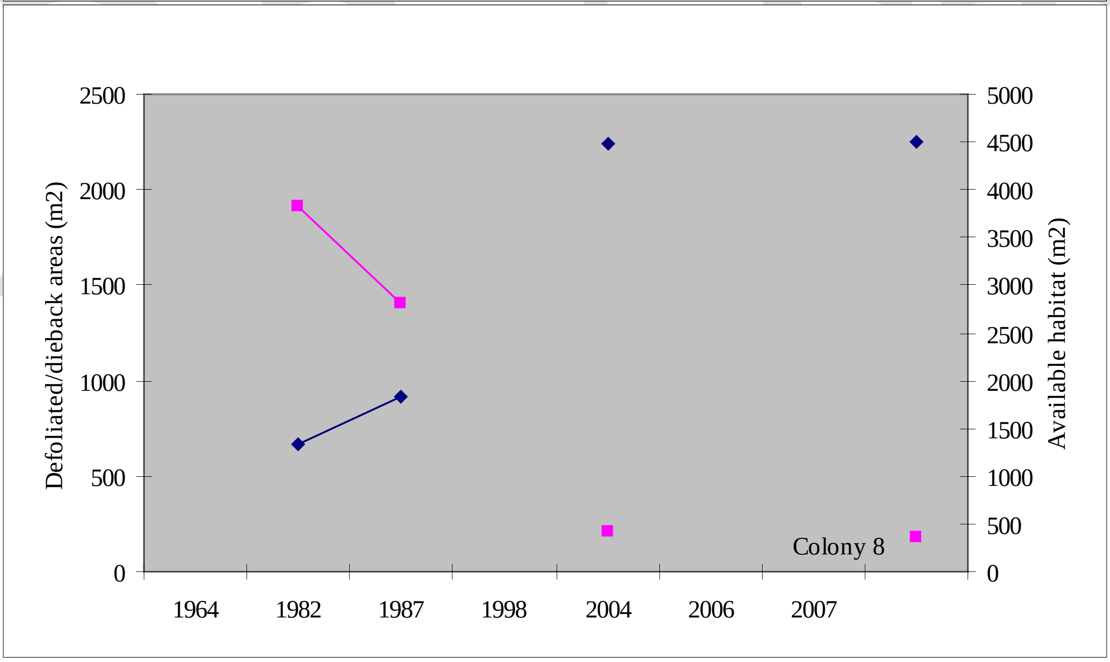
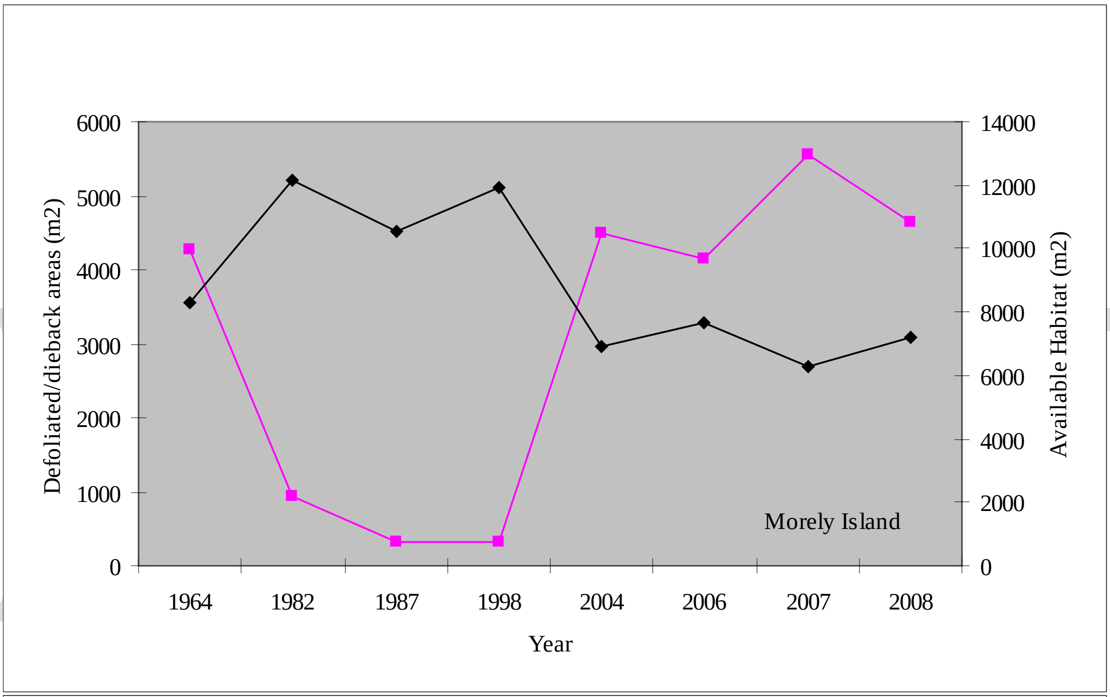


Figure 11: The estimated area (m^2) of total available nesting habitat and total areas defoliated or undergoing dieback for the main colonies of Lesser Noddies at Morley Island (top) and Wooded Island (bottom) between 1964-2008. The black line represents available habitat, pink line areas of dieback and red line the area occupied by the Pied Cormorant colony on Wooded Island.



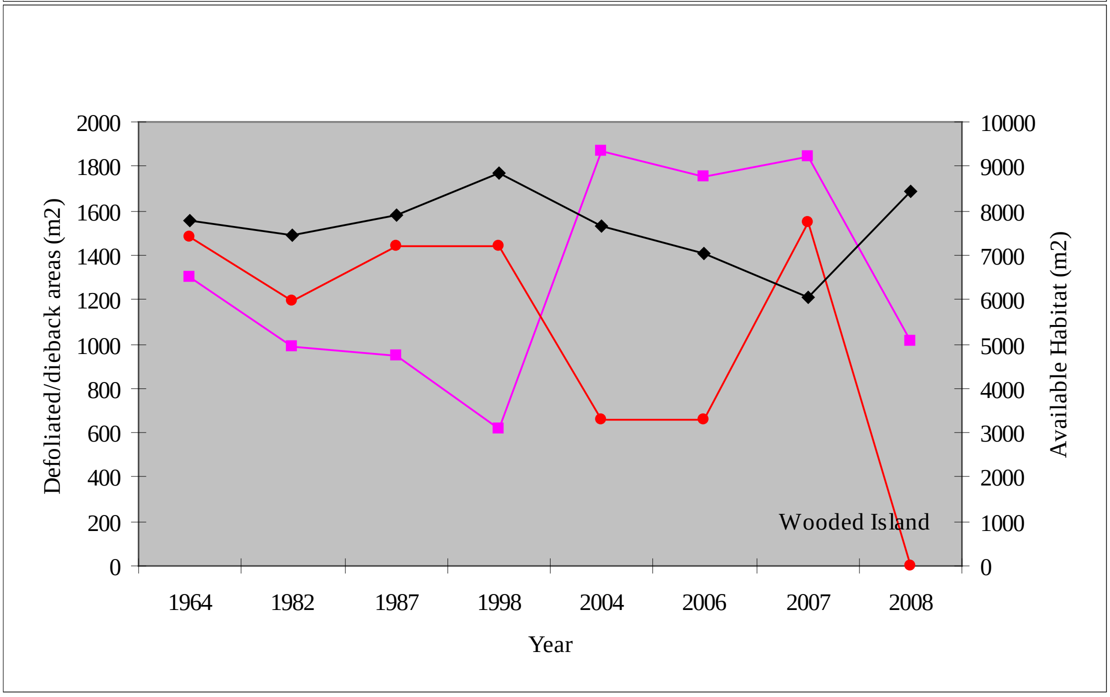


Figure 12: The estimated area (m^2) of total potential nesting habitat and total areas defoliated or undergoing dieback for mangrove areas at control islands 1998-2006. The black line represents available habitat, and the pink line areas of dieback.

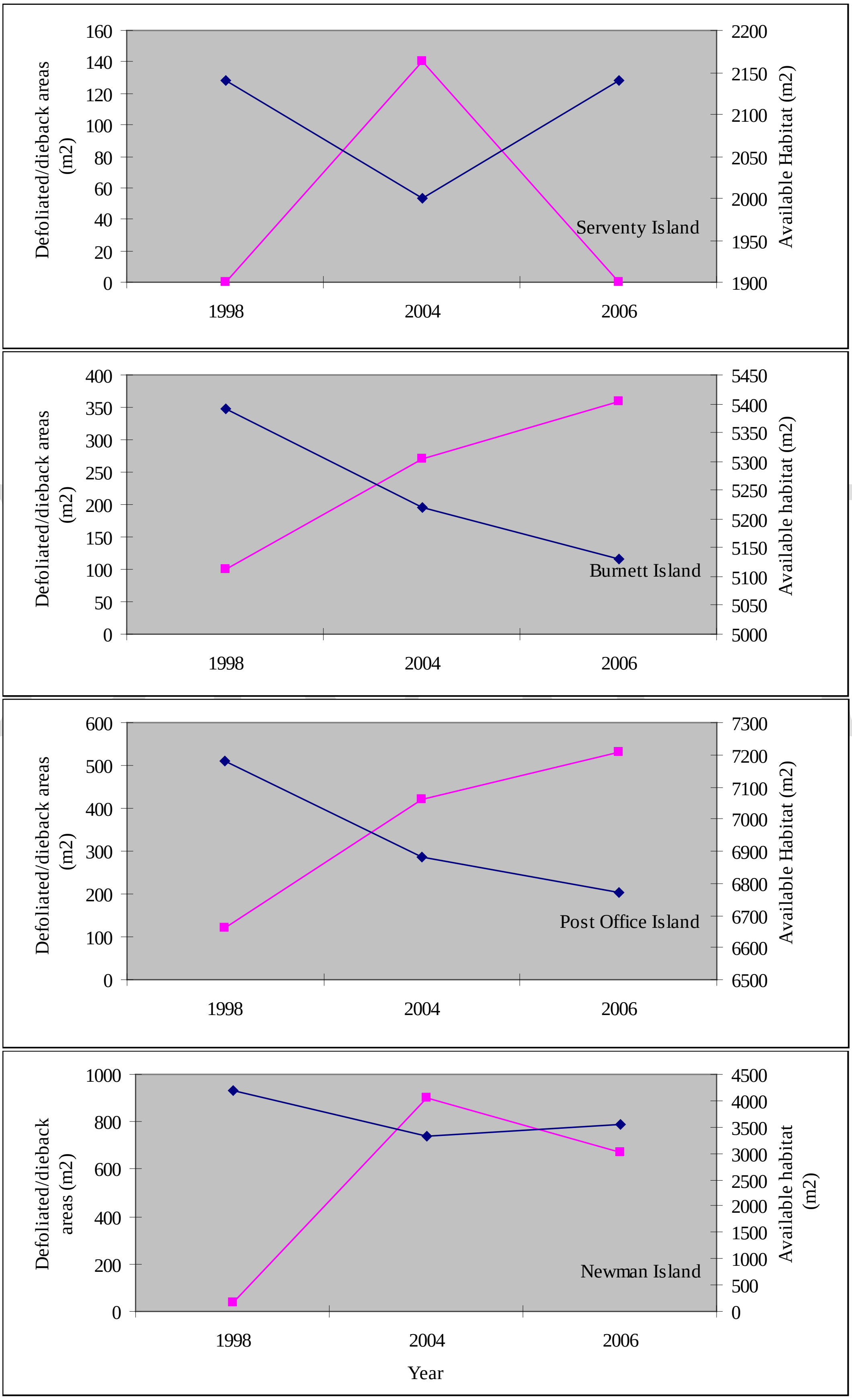


Figure 12 shows the amount of available habitat and mangal dieback in “control” sites (those areas of mangrove known to have not been inhabited by Lesser Noddies in the past 60 years) since 1964. These figures illustrate that even areas of mangrove not utilised by Lesser Noddies experienced some degree of dieback, and this was particularly noticeable between 1998 and 2004 on Newman, Post Office and Burnett islands in the Pelsaert Group.

Table 3: The percentage of total mangrove habitat for each colony that was affected by defoliation or dieback between 1964-2008. Data estimated from aerial photographs provided by Landgate (1964 – 2006) and taken from fixed wing aircraft in 2007 and 2008.

		Year								
Island	**Colony**	**1964**	**1978**	**1982**	**1987**	**1998**	**2004**	**2006**	**2007**	**2008**
Pelsaert	1	1.4	0.0	0.0	0.0	6.1	4.7	6.5	7.6	7.6
	2	2.4	0.0	0.0	0.0	5.8	13.2	9.8	12.6	12.6
	3	9.2	-	9.9	12.4	11.7	8.7	11.0	6.0	5.3
	4	8.1	-	10.1	0.0	1.2	0.0	3.4	0.0	0.0
	5	11.4	-	10.2	20.7	4.6	2.6	2.4	0.7	0.7
	6	4.8	-	9.2	6.3	6.3	39.2	35.2	11.1	9.2
	8	-	-	58.9	43.2	-	4.5	-	-	3.8
Wooded		12.3	-	10.3	9.2	5.7	18.4	18.5	19.5	10.7
Morley		34.0	-	7.1	2.9	2.5	39.6	35.0	46.9	39.3
Serventy						0.0	7.0	0.0		
Burnett						1.9	5.2	7.0		
Post Office						1.7	6.1	7.8		
Newman						0.9	27.1	18.9		

The cyclic nature of increase/decrease in defoliation between colony areas and islands revealed in Table 3 confirms that two factors appear to influence mangrove health at the Houtman Abrolhos. Firstly, Lesser Noddy nesting creates severe exposure (and subsequent noddy habitat loss), and is most likely due to the increased nutrient levels from guano which has built up over the previous years occupation. The longer term movements of Lesser Noddies between the colonies on Pelsaert Island with cycles of abandonment from some areas and recolonisation elsewhere, coincides with increasing percentages of dieback. Secondly, a more recent drought period associated with decreased rainfall has resulted in dieback at mangroves not associated with Lesser Noddy colonies. Since 1998 this dieback has left some areas severely affected, for example Newman Island, and others, like the extensive mangal at Colony 5 on Pelsaert Island unscathed. The degree of deterioration in mangroves at each site is most likely influenced by the degree of regular tidal flushing, as well as the effect and location of freshwater lenses that may occur underground.

The average annual rainfall at Geraldton has been 451mm, while that recorded at the Houtman Abrolhos in recent years has been significantly lower, averaging 270mm. Since 1997, when evidence of mangrove dieback became obvious, the average rainfall in Geraldton has been 391mm, with nine of the last eleven years (since 1997) recording below average rainfall (Figure 13). More recently, drought conditions have prevailed, with only 298mm falling in 2002, 340mm in 2004, 197 mm in 2006 and 231mm in 2007. Lower rainfall could certainly be attributed to changes in mangrove health observed at the Houtman Abrolhos.

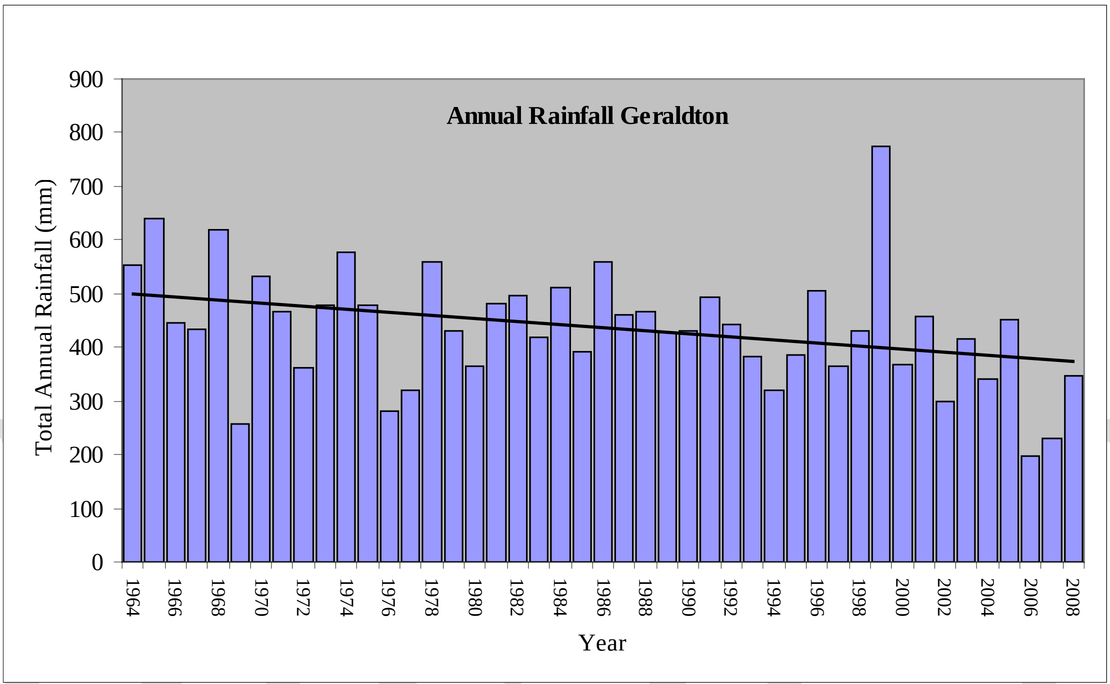


Figure 13: The annual total rainfall (and trendline) at Geraldton between 1964 and 2008.

Interestingly, Colony 5 on Pelsaert Island had fully recovered from a period in the 1980's where up to 21 % of total cover was affected by defoliation and dieback. Lesser Noddies last nested in this area in 1991, and had only just returned to the area in 2005. Their return to the area coincided with the mangroves' return to health (only 0.7% dieback in 2007) and a decline in mangrove cover at the Lesser Noddy Lakes (Colonies 1 &2) 2km further to the south. In 2008 we reported a 250 % increase in the population at this site (Table 4, 5) and anticipate that numbers here will continue to increase in the medium term.
Although earlier imagery is of poorer quality, the levels of dieback on Pelsaert Island suggest that the Big Lagoon colony (Colony 5) was most likely densely occupied by Lesser Noddies and the two southern colonies around the Lesser Noddy Lakes were recovering and regrowing.

Dieback at both Wooded and Morley Islands had also undergone cyclic change with relatively low levels of dieback in 1998, which then increased significantly between the 1998 and 2004 aerial images. The high nutrient loads, coupled with occupation by Lesser Noddies, had exacerbated the effects of the drought period in these areas.

3.6 Population Estimates

Table 4: The mean nesting density (nests/20m^2) and mean estimated population sizes for Lesser Noddy colonies at the Houtman Abrolhos during 2006 and 2008 (see text for explanation). We counted all nests in each quadrat and assigned each nest a status based on previous observations collected by Surman. Population estimates were then calculated using the mean density for the maximum total population (including unused nests), the total potential breeding (including those nests found empty and unused but excluding old abandoned sites) and the mean actual breeding population based on observed participation (those nests with active breeding attempts).

			Nest Density			**Population Size (pairs)**		
Island	**Colony No.**	**Colony Area (m^2)**	**Mean total nests**	**Mean recent nests**	**Mean Active nests**	**Mean Max Pop^n**	**Mean Potential Breeding**	**Mean Actual Breeding**
2006/07								
Pelsaert	1	13 610	33.4 (0.8)	20.6 (0.6)	9.2 (0.3)	22 712 (2105)	14 007 (1744)	6 294 (830)
	2	11 280	41.8 (3.6)	37.9 (3.5)	24.6 (2.6)	23 605 (2048)	21 366 (2001)	13 868 (1477)
	3							
	4							
	5	4 330	15.6 (3.9)	14.2 (3.8)	9.6 (2.6)	3 356 (1084)	3 193 (1051)	2 273 (670)
	8	4 690	16	12	6	192	192	192
							38 758	**22 627**
Wooded		7 050	41.4 (7.4)	33.9 (6.3)	12.7 (2.9)	15 488 (2519)	12 712 (2162)	4 758 (1050)
Morley		7 690	48.8 (7.1)	43.8 (6.4)	15.1 (2.3)	20 647 (2580)	18 532 (2355)	6 718 (1383)
Total							**70 002**	**34 103**
2007/08								
Pelsaert	1	13 460	29.9 (4.0)	15.1 (2.2)	7.3 (1.2)	24 111 (2602)	12 377 (1474)	6 873 (1060)
	2	10 930	35.2 (3.4)	24.4 (2.8)	13.7 (1.7)	20 254 (1773)	13 745 (1479)	8 722 (1404)
	3							1 449
	4							454
	5	4 330	24.2 (4.9)	22.5 (4.7)	7.1 (1.7)	5 646 (1060)	5 245 (1003)	2 135 (513)
	8	4 690						548
						50 011	**31 367**	**20 181**
Wooded		6 060	29.2 (5.6)	16.6 (3.7)	6.6 (1.9)	11 702 (1899)	6 709 (1300)	3 216 (601)
Morley		6 280	47.6 (9.7)	29.5 (5.9)	16.5 (3.6)	17 187 (3239)	10 758 (1912)	6 958 (1446)
Total						**78 900**	**48 834**	**30 355**

			Nest Density			Population Size (pairs)		
Island	**Colony No.**	**Colony Area (m^2)**	**Mean total nests**	**Mean recent nests**	**Mean Active nests**	**Mean Max Pop^n**	**Mean Potential Breeding**	**Mean Actual Breeding**
2008/09								
Pelsaert	1	13 460	30.6 (3.6)	17.4 (2.9)	10.9 (2.2)	23 070 (2 520)	13 628 (2 283)	9 391 (1 780)
	2	10 930	33.8 (3.4)	25.0 (2.9)	17.5 (2.2)	19 061 (1 830)	14 093 (1 577)	9 837 (1 196)
	3	1 470	31.2 (5.1)	26.4 (5.2)	11.0 (2.3)	2 293 (377)	1 940 (385)	764 (142)
	4	830	56.0 (14.1)	51.3 (11.3)	31.3 (8.4)	2 324 (584)	2 130 (470)	1 300 (347)
	5	6 040	28.8 (4.7)	25.4 (4.0)	19.9 (3.3)	10 325 (1 564)	9 043 (1 320)	7 476 (1 094)
	6	1 470	0.8 (0.4)	0.8 (0.4)	0	62	62	62
	8	1 590	70.0 (22.0)	64.0 (19.1)	30.0 (7.2)	4 614 (1 751)	4 291 (1 518)	2 136 (574)
Wooded		8 440	41.5 (9.52)	29.3 (8.6)	18.1 (5.5)	18 328 (4 212)	12 936 (3 798)	7 985 (2 437)
Morley		7 180	52.3 (9.4)	36.6 (6.5)	23.6 (4.6)	18 762 (3 359)	13 502 (2 416)	8 955 (1 728)
Total						**98 839**	**71 625**	**47 906**

Table 4 above shows some important population trends since intensive surveys continued in 2006. There were significant proportions of unused nest sites, as indicated by the presence of old nests (see Figure 1, Figure 6) with no new material added or guano indicating occupation. The proportion of unused nest sites would be expected to be greatest at the older colonies (i.e. Pelsaert Colonies 1 and 2, Wooded and Morley Island colonies) compared with the newly colonised areas on Pelsaert (i.e. colonies 3, 4, 5 and 8). Table 5 confirms this, with an average 38.4% of old nests at established colonies compared to only 8.8% at the more recently colonised areas.

Table 5: The percentage of nests counted that were classified as "old", i.e. not having been used or attended since the previous breeding season, for each colony surveyed. The mean percentage of old nests for established and newer colonies are also given.

Island	Colony	2006	2007	2008
Pelsaert	1	40.6	48.4	51.4
	2	11.8	34.9	27.5
	3	-	4.5	16.8
	4	-	11.4	7.0
	5	4.9	7.2	12.4
	8	-	2.8	7.7
Wooded		19.4	47.2	44.1
Morley		12.0	32.7	30.6
Established Colony Mean		20.9	40.8	38.4
New Colony Mean		4.9	6.4	8.8

There was an increase in the numbers of total nests as well as the number of active nests at each of the major nesting colonies surveyed in 2008. The most significant increases were observed on Wooded Island, Morley Island and Colony 5 on Pelsaert Island (Table 4). It appears, based on observations of less mangrove dieback, and increases in breeding birds, that the deterioration on Morley Island had reached its peak in the previous season. Bushy regrowth could be seen in the fringe areas of mangroves where dieback had occurred.

In Table 6, the population estimates presented as Mean Potential Breeding pairs have been calculated using the most similar method to that used by Phil Fuller and Andrew Burbidge for the population estimates presented in their surveys. The Mean Actual Breeding pairs represents a more accurate estimate of the level of breeding participation in the population in any year, as we differentiate between those nests that "look" like they "may" have an attempt from those later known to have been used.

The results show an overall increase from 30 355 breeding pairs in 2007/08 to 47 906 breeding pairs in 2008/09, a population increase of 57 %. Much of this change was attributable to a general increase in the numbers of birds participating to breed across all colonies in the 2008/09 season.

3.7 Long-term Population Trends

Figure 14 and Table 7 show the estimated numbers of breeding pairs at each island at the Houtman Abrolhos between 1986-2008. Estimates were only obtained for Pelsaert Island in 1986 (Burbidge and Fuller 1989). There is considerable variation in the numbers of pairs attempting to breed in any one year however the longer term trend for each island is a steady decline. Fuller *et al.* (1994) reported a total of 77 360 pairs in the 1989 season compared to the lowest breeding population size recorded of 30 355 pairs during the 2007 season. We report some recovery in the numbers of breeding birds, to an estimated 47 906 pairs in 2008. It should be noted here that this does not reflect new recruitment to the colonies from a cohort of immature birds, but rather that a significant proportion of adult birds of breeding age had returned to nest in the 2008/09 season. It also indicates that in any one year a significant proportion of breeding adults are no longer participating. Although this may in part be due to a decrease in nesting habitat, it may also reflect a decline in food resources adjacent to the Houtman Abrolhos.

From 1989 to 1993 the total population declined to 48 885 pairs, but increased until reaching a more recent peak in 1999 of 67 985 pairs (Burbidge and Fuller 2004). The current active breeding population still remains at 62 % of the 1989 population. However, it is impossible to measure the non-breeding component of the population, and a return to higher participation levels in the future can not immediately be discounted at this stage.

The last peak in 1999 coincided with a return to earlier nesting (see Figure 5) in Lesser Noddies after a period of very late breeding and very low success rates. Earlier nesting results in both higher participation rates and breeding success rates for the population of Lesser Noddies. It is possible then that there were a considerable proportion of birds of breeding age that did not attempt to breed in the past two seasons.

Figure 14: The estimated numbers of breeding pairs of Lesser Noddies at each island at the Houtman Abrolhos between 1986-2008.

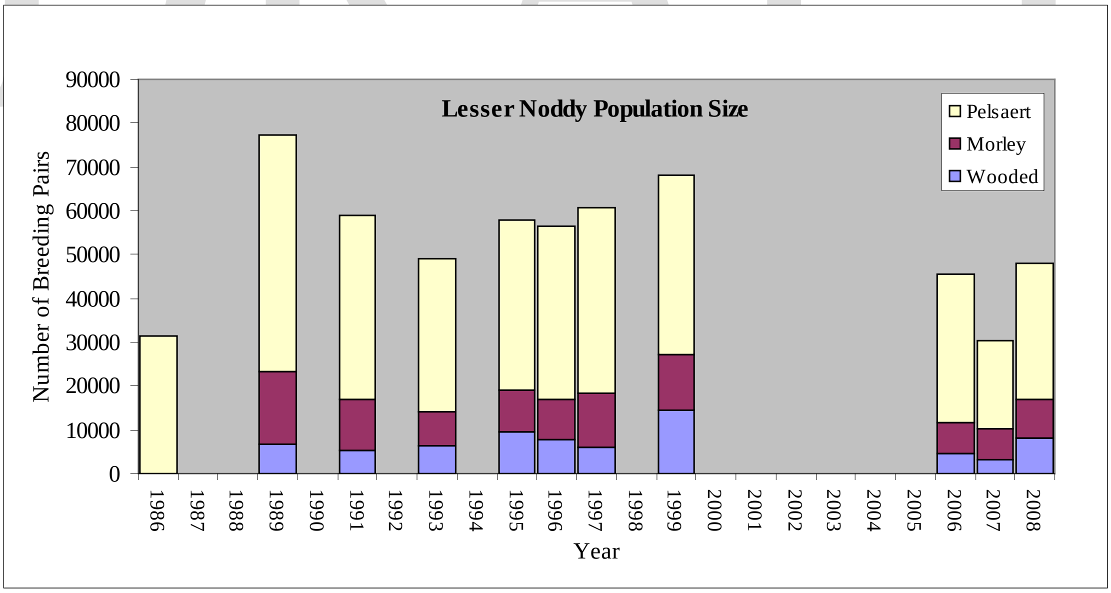


Table 7: The estimated numbers of breeding pairs of Lesser Noddies on Pelsaert, Wooded and Morley Islands between 1986-2007.

Colony	1986	1989	1991	1993	1995	1996	1997	1999	2006	2007	2008
1	13 994	28 900	26 422	20 107	19 700	21 020	24 030	26 196	6 294	6 873	9 391
2	8 941	21 615	14 016	14 763	19 100	18 440	18 300	14 490	13 868	8 722	9 837
3	20	0	0	0	0	0	0	0		1 499	764
4	110	0	0	0	0	0	0	0		454	1 300
5	7 736	3 480	1 220	0	0	0	0	0	2 273	2 135	7 476
6	597	115	86	0					0	0	62
7	30	0	0	0					0	0	0
8	0	0	0	0					192	548	2 136
9	0	0	0	0					0	0	0
10	0	0	0	0					0	0	0
Wooded		6 875	5 323	6 325	9 570	7 920	6 075	14 485	4 758	3 216	7 985
Morley		16 375	11 745	7 665	9 600	8 930	12 300	12 800	6 718	6 958	8 955
Total		**77 360**	**58 812**	**48 860**	**57 870**	**56 310**	**60 705**	**67 971**	**34 103**	**30 355**	**47 906**

Sources: Burbidge and Fuller (1989), Fuller *et al.* (1994), Burbidge and Fuller (2004), Surman and Nicholson (2007).

3.8 Historical summary from references

In order to understand the historical context of the cyclic changes in mangrove habitat, and the relationship with Lesser Noddy nesting, it is useful to compare observations made by previous ornithological visitors to the Houtman Abrolhos (Table 8).

Table 8: Historical summary of events recorded by ornithologists regarding Lesser Noddies at each of the main colonies with a focus on movement between islands and colonies from 1842-2008.

Year	Colony	Comments	Reference
1842	Pelsaert	Lesser Noddies discovered by Gilbert on Pelsaert Island.	Alexander (1922)
1890	Pelsaert	Campbell photographs noddies at Pelsaert Island.	
1894	Pelsaert	Continued nesting on Pelsaert Island.	Lipfert
1897	Pelsaert	Continued nesting on Pelsaert Island.	Helms (1902)
1899	Pelsaert	Continued nesting on Pelsaert Island, estimated lay date 20 Sept 1899.	Hall (1902)
1907	Wooded	Pelsaert colony deserted, established on Wooded Island with hundreds of thousands.	Alexander (1922)
1913	Wooded	Dense colony, dieback of mangroves first noted.	Alexander (1922)
1915	Wooded	Fewer birds nesting on Wooded Island.	
1936	Pelsaert	Noddies back on Pelsaert colonies 1 & 2, none at Big Lagoon (colony 5), Early year-breeding commenced in late August.	Sandland (1937)
1941	Morley	First record of 1000 birds at Morley Island.	Serventy
1941	Pelsaert	Serventy estimated ~6000 prs.	Serventy
1942	Pelsaert	Estimated 20,000.	Serventy (1943)
1943	Pelsaert	Serventy maps colonies 1 & 2, observed only ~100prs at colony 2. Dense at colony 1. Lay date estimated at 28 September.	Serventy

1944	Pelsaert	Serventy's 1943 observations repeated in 1944.	Serventy[1]
1945	Pelsaert	Large numbers inhabiting both colonies 1 & 2 on Pelsaert, none at Colony 5.*	Serventy[1]
1945	Morley	Colony deserted.	Serventy[1]
1948	Pelsaert	Very early year. Estimated lay date mid-late August.	
1953	Pelsaert	Colony occupied.	Ealey (1954)
1954	Pelsaert	Colony occupied.	Warham (1956)
1961	Pelsaert	Fresh eggs on 17 Sept.	T.C. Allen[1]
1963	Pelsaert	Colony occupied.	Serventy (1964)
1964	Pelsaert	Colony occupied.	P.S. Stone[1]
1973	Pelsaert	Colony occupied.	N. Kolichis[1]
1977	Pelsaert	No laying on 28 October, late start.	P.J. Fuller[1]
1978	Pelsaert	Very few attempts, very few fledglings, likely breeding failure.	P.J. Fuller[1]
1979	Pelsaert	Not at Big Lagoon.	Baker (1979)
1980	Pelsaert	Observed at Big Lagoon, late commencement, few eggs on 27 November. Colony 10 first used.	Fuller and Burbidge (1992)
1981	Pelsaert	Colony occupied.	R.E.Johnstone [1]
1982	Pelsaert	All colonies 1-10 used.	Fuller and Burbidge (1992)
1983	Pelsaert	Colony 1 & 2 occupied.	R.E.Johnstone [1]
1984	Pelsaert	All colonies 1-10 used.	Fuller and Burbidge (1992)
1986	Pelsaert	Colonies 8-10 abandoned.	Fuller and Burbidge (1992)
1989	Pelsaert	Colonies 3, 4 and 7 abandoned.	Fuller and Burbidge (1992)
1991	Pelsaert	Colonies 1 & 2, 5 & 6 occupied.	Surman (1992)
1992	Pelsaert	Colony 5 & 6 abandoned.	Surman *pers obs*
1996	Pelsaert	Dieback noticed.	Surman *pers obs*
1999	Pelsaert	Final population estimate by Fuller and Burbidge.	Burbidge and Fuller (2004)
2006	Pelsaert	Colony 3-5 and 8 recolonised. New population estimates.	Surman and Nicholson (2007)
2006	Wooded	Pied cormorant colony in south eastern mangroves. Dieback extensive.	Surman and Nicholson (2007)
2006	Morley	Dieback and unoccupied areas extensive. First mapping undertaken.	Surman and Nicholson (2007)
2007	Pelsaert	Colonies 1-5, 8 all occupied.	Surman and Nicholson (2008)
2007	Wooded	Large Pied Cormorant colony at west end of mangrove.	Surman and Nicholson (2008)
2007	Morley	Extensive areas unoccupied due to dieback.	Surman and Nicholson (2008)
2008	Pelsaert	Colonies 1-6, 8 all occupied. Large increase in density at Colony 5, recent establishment at Colony 6.	Surman and Nicholson (2009)
2008	Wooded	Pied Cormorants moved to area outside of main mangal. Sooty Terns nesting under mangal.	Surman and Nicholson (2009)
2008	Morley	Some very slight recovery of mangal health	Surman and Nicholson (2009)

*an aerial photo in Teichart 1947 probably pre 1946 shows extensive dieback at the colony 5, similar in extent to that observed in 1987. [1] From notebook records from W.A. Museum.

The observations outlined above confirm the more recent trend of cyclic mangrove deterioration described in this report, and illustrated with aerial imagery. Interestingly, an aerial photo in Teichart (1947), probably pre 1946 (Figure 15), shows extensive dieback at Colony 5 (Big Lagoon, Pelsaert Island), similar in extent to that observed in 1987. This indicates that Lesser Noddies had been nesting here in the period prior to 1945 and may have been missed the visits of Serventy.

Similarly a photo taken in 1907 during Gibson's (1908) visit to Wooded Island clearly showed large, defoliated mangrove trees at this site. However, in spite of this Gibson (1908) still found *"..hundreds of thousands of birds were breeding in a mangrove thicket"*. The apparent abandonment of the Pelsaert Island mangroves between 1899-1907, and the dense nesting observed by Gibson at Wooded Island, most likely led to the severe dieback illustrated in the image, and the eventual return of Lesser Noddies to the Pelsaert mangroves sometime between 1916-1936.

Dead timber was also recorded by Sandland (1937) during his November 1936 visit, and included a photo of the Pelsaert Island sites at colonies 1 & 2, which showed extensive areas of defoliated mangrove.

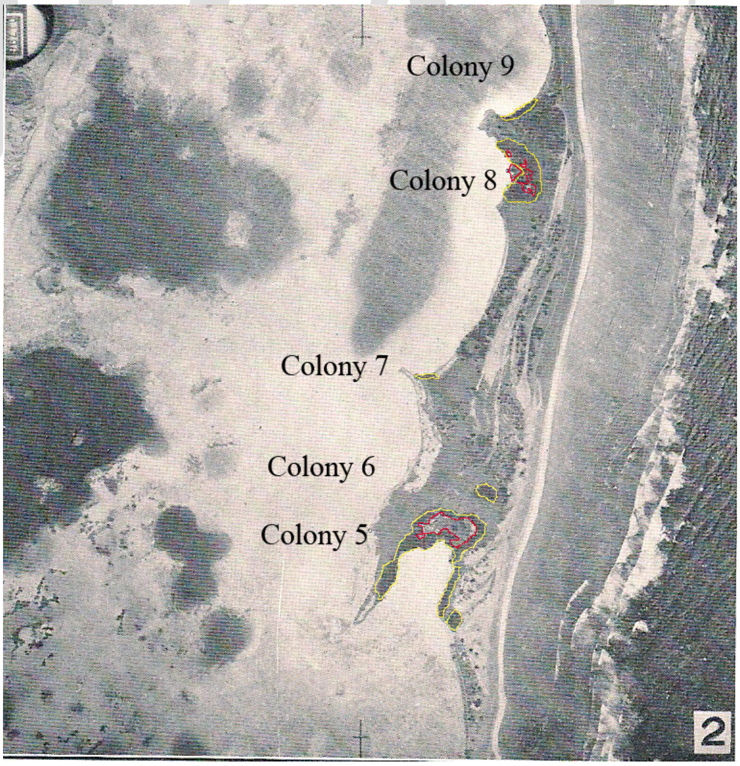


Figure 15: An unsourced aerial image of the Big Lagoon, Pelsaert area taken pre 1946 (see Teichart 1947). Mangrove areas are bounded by yellow lines and dieback/bare areas by red. The state of colony 5 and colony 8 is similar to that observed more recently in 1964 and 1982 and would indicate recent heavy occupation by Lesser Noddies.

3.9 Causes of Mangrove dieback

Mangroves worldwide are known to experience cyclic periods of growth and senescence (Cintron *et al.* 1978). These changes in mangrove area may be due to the effect of cyclones and rainfall that influence both the structure of the mangal through destructive winds, and the quality of soil water through fresh water flushing. Changes in canopy cover brought about by natural defoliation also influences seedling recruitment to the mangal, especially where soil temperatures may be extreme. In Colombia, the seedlings of *A. marina* were killed when soil temperatures were greater than 45^{o}C (i.e. in exposed areas, Elster *et al.* 1999).

The mangroves found at the Houtman Abrolhos, *A. marina*, are the most salt and temperature-tolerant of mangrove species (Clough 1984, Ball 1988, Elster *et al.* 1999). However, their position along the high water marks of rocky shores and around tidal ponds is not ideal due to the low soil water holding ability of these areas, and the constant high salinity, elevated beyond that of seawater by high evaporation rates. Recruitment to the existing mangrove population is also limited on the Houtman Abrolhos by extensive patches of bare substrate, as well as a lack of accumulating areas on beaches, where tidal action may trap propagules. Thus, it is reasonable to assume that the mangroves of the Houtman Abrolhos are growing at the very limit of their physiological tolerance.

The recent decline in mangrove health has occurred since 1996 at the Houtman Abrolhos. Analysis of historical aerial photographs shows that this trend has also occurred in the past, most notably at those mangroves containing Lesser Noddy colonies. There has been significant dieback at the Big Lagoon colony 5 and Colony 8 that has peaked previously in 1964 and1987, and by inspection of the figure scanned from Teichart (1947) sometime in 1946 or before. Similarly, these same images show a similar trend for both Wooded and Morley Islands over the same period. Data collected in 2008 show that signs of recovery, albeit slight, were beginning to show at the most severely affected sites.

4 Conclusions

Lesser Noddies at the Houtman Abrolhos remain under threat from the potential impacts of sealevel change. Currently, the population of Lesser Noddies remains in a long term decline, although there were more breeding in the 2008/09 season. On average, data from 2001-2008 (compared to data collected between 1991-2000) indicate that fewer are breeding, they are breeding much later than expected and they are producing fewer young.

The health of mangroves and amount of foliar cover of mangroves at the Houtman Abrolhos has been influenced by two major environmental factors since at least the turn of the 20th century. Firstly, nesting Lesser Noddies or Pied Cormorants and the subsequent increase in guano deposition and therefore nitrification, has been found to have caused not only mangrove dieback, but also the forced migration between mangrove areas of Lesser Noddies. Secondly, between 1994 and the present day some mangroves not associated with Lesser Noddy nesting have also experienced defoliation and dieback. This second cause is most likely associated with recent ENSO driven drought conditions.

Lesser Noddies are known to be mate and site faithful, as well as being long-lived, with some banded individuals known to be at least 19 years old. However, as a result of the instability of their nesting habitat over the longer term, the birds will move nesting sites at both an individual and community level.

Population estimates at each island show a longer-term downward trend. This may be linked to an increase in the frequency of later-breeding years due to an increase in the frequency of ENSO events, which are characterised by poor levels of participation and low breeding success. The last breeding season in which Lesser Noddies bred early was in 1999, and the trend for this and other colonial species is towards later breeding having shifted on average 30d since the early 1990's.

Sealevel rise will no doubt alter the current stands of mangroves that exist at the Houtman Abrolhos. Habitat undergoes cyclic change, as demonstrated by the historical analysis presented in this report, but how will this trend be influenced going forward with predicted sealevel change? There is a risk that those mangrove areas situated along the coastline will be subjected to greater stress as a result of storm events and associated erosion, an increase in ENSO- induced drought and other factors associated with the consensus predictions for the impact upon sea levels from global warming.

The recent increase in the numbers of adult Lesser Noddies participating in breeding during the 2008/09 season indicates that there were a considerable proportion of adult birds not participating in poor years, such as that observed in 2007/08. However, the data suggests that reproductively poor years are becoming the status quo, and therefore we can expect further long-term decline in the breeding population at this site. As we have found the Lesser Noddy to be a robust indicator of the general health of the Houtman Abrolhos system for other seabird species, the future for seabirds at this most important breeding site appears rather uncertain.

5 Recommendations

We recommend:

- Continued intensive annual monitoring of Lesser Noddy colonies at the Houtman Abrolhos as a minimal requirement to assess changes in conditions for seabirds at this site.
- Ongoing population census of seabirds across the Houtman Abrolhos.
- Management measures to identify and secure currently uninhabited mangrove areas as potential future noddy nesting habitat.
- Collaboration between the DEC, DoF and AIMAC to secure funding to maintain this unique database as a management tool for seabirds at one of Australia's most significant seabird breeding sites.

6 Outcomes/deliverables

- Trends in Population and Habitat Status in the Threatened Lesser Noddy *Anous tenuirostris melanops* at the Houtman Abrolhos. Presentation to the NACC, DEC and AIMAC at Geraldton DEC, July 2009.

- The Amazing Seabirds of the Houtman Abrolhos. Public Lecture. W.A. Museum, Geraldton, July 2009.

- Radio Interview. ABC Regional – Mid West Region. July 8 2009.

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