Corella, 2016, 40(3): 69-75

Long-term population trends in the vulnerable Lesser Noddy *Anous tenuirostris melanops* at the Houtman Abrolhos, Western Australia

Chris A. Surman[1], Andrew A. Burbidge[2] and John Fitzhardinge[3]

[1]Halfmoon Biosciences, 45 Heather Road, Ocean Beach WA 6333, Australia
Email: halfmoon.biosciences@westnet.com.au
[2]87 Rosedale St, Floreat, WA 6014, Australia
[3]Dongara Marine, 2 Carrol St, Port Denison WA 6525, Australia

Received: 23 April 2015

Estimated numbers of breeding pairs of the Lesser Noddy (Houtman Abrolhos) *Anous tenuirostris melanops* are reported from 14 surveys made between 1986 and 2014. Numbers on the three breeding islands, Pelsaert, Wooded and Morley, have fluctuated between years and within colonies. Total estimated numbers of breeding pairs for the Houtman Abrolhos population have varied from c. 77 000 in 1986 to *c.* 48 000 in 1993 and 2007; however, in most cases a lower number in one year has been followed by higher numbers in succeeding years. There has been decline in numbers since 1986, with both 2013 and 2014 both having relatively low estimates. Lesser Noddies nest only in Grey Mangrove *Avicennia marina* low forests and there has been considerable mangrove dieback during the past two decades, with Morley Island being particularly affected. The subspecies clearly meets IUCN Red List criteria for *Vulnerable*, and if a precautionary approach is taken to evaluation, could meet criteria for *Endangered.*

INTRODUCTION

The Australian subspecies of the Lesser Noddy *Anous tenuirostris melanops* nests in Grey Mangroves *Avicennia marina* on three islands in the Houtman Abrolhos, off Geraldton, Western Australia. Because of the very small 'Area of Occupancy' during breeding (less than 4 ha) and declining numbers, it is listed as *Vulnerable* under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth), and because more recent data showed a significant decline, as *Endangered* under the *Wildlife Conservation Act 1950* (WA). In *The action plan for Australian birds 2010* (Garnett *et. al*. 2011) it was evaluated as Endangered B2ab(iii,v) using IUCN Red List Categories and Criteria. It also meets Vulnerable D2, having a population with a very restricted area of occupancy and plausible threats (mangrove decline, and decline in food supply due to changes in the strength of the Leeuwin Current).

Estimates of the number of breeding pairs on each island were provided by Burbidge and Fuller (1989, 2004), Fuller *et al*. (1994) and Surman and Nicholson (2009a), with the last of these showing a significant decline in numbers of breeding pairs. In this paper we report the unpublished data of Surman and Nicholson (2009a) and counts since that time, and examine trends in the size of the breeding population. While, in recent years, we attempted to make quadrat counts near the peak of the season, this was not always possible for logistical reasons. Thus, comparing data on nests in use is of limited value and the best estimate of the number of breeding pairs is calculated using nests in use plus those under construction. We also report on mangrove dieback and how it may have affected Lesser Noddy breeding pair estimates.

METHODS

Transects have been maintained through all breeding colonies since 1986 (Burbidge and Fuller 1989). A total of ten transects on Pelsaert Island, three transects on Morley Island and five transects on Wooded Island were surveyed (Figure 1). One additional transect was added on Morley Island to increase sampling rate after significant death of mangroves there (see below). All nests two metres each side of a central permanently-marked line (the Transect) were counted. Each transect was broken down into continuous five metre long sections, with the result that each survey quadrat (4 x 5 m) covered 20 square metres. Each transect commenced at one edge of the mangal and bisected a section to the opposite edge, usually orientated roughly in a west to east direction (Figure 1 and Table 1).

From 1986 to 1999 nest counts took place on five occasions and all occupied nests (egg or chick) or nests judged to be under construction or to have been recently used during that breeding season were counted. Surman (1997) quantified the status of nests in order to better assess the status of breeding, differentiating nests containing old nesting material from previous seasons with those of the current season including nests under construction or refurbishment. Data from the 2006/07, 2007/08, 2008/09, 2013/14 and 2014/15 breeding seasons included nests with an assigned status as follows:

1. Old – existing nest containing material from previous nesting seasons
2. Sargo – nests recently refurbished with fresh brown algae (Sargassaceae)
3. Ulva – nests recently added to with brown algae and lined with sea lettuce (*Ulva lactuca*, Ulvophyceae)
4. Egg – nests containing an egg or an adult incubating an egg
5. Chick – nests containing a chick, these were also categorised by age class
6. Chick guano – recently constructed nests with a guano ring along outer edge
7. Dead Chick – nests containing a dead chick
8. Abandoned – nests containing an addled, cracked or abandoned egg.

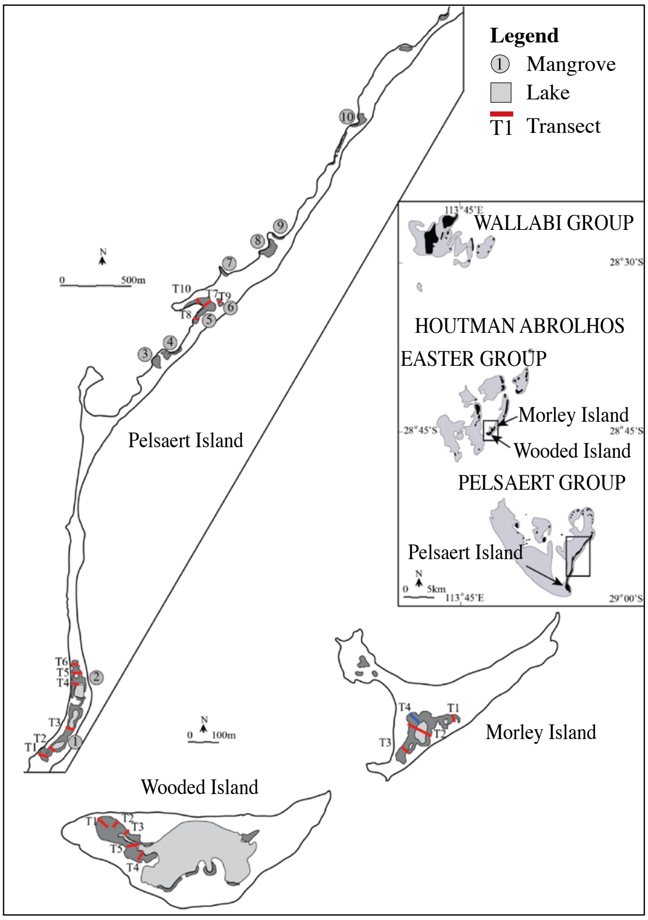

Figure 1: *Location map showing the three islands surveyed (Wooded, Morley and Pelsaert) and the approximate location of survey transects monitored.*

Table 1

The location, number and size of monitoring transects on Pelsaert, Morley and Wooded Islands, Houtman Abrolhos.

Island	Transect	No. of Quadrats	Length (m)
Pelsaert	1	13	65
	2	7	35
	3	8	40
	4	11	55
	5	13	65
	6	10	50
	7	14	70
	8	5	25
	9	3	15
	10	5	25
Total	**10**	**89**	
Wooded	1	8	40
	2	6	30
	3	5	25
	4	4	20
	5	6	35
Total	**5**	**29**	
Morley	1	10	50
	2	13	65
	3	8	40
	4*	6	30
Total	**3**	**37**	

* Transect No. 4 was added in 2014, shown in Fig. 1 in blue

The estimated number of breeding pairs for a breeding season was calculated using nests from categories 2 to 8 above. As nesting is not synchronised, the inclusion of nests relined with fresh marine algae allowed an indication of pre-laying activity and prediction of those nests likely to contain an egg at a later date. For breeding seasons since 2006/07, we also calculated nests in use at the time of the quadrat counts; these were the sum of categories 4 to 8. 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 of mangroves occupied in that colony for that year (Table 3).

Lesser Noddy pairs use a single nest in a breeding season, and can re-lay in that nest if the initial breeding attempt fails (Surman and Wooller 1995); thus a second breeding attempt in one season does not result in over-estimating the number of breeding pairs.

Visit dates relating to new data reported here were:

- 2006/07 breeding season: Pelsaert Island 3–5 December; Wooded Island 11 December; Morley Island 12 December 2006.
- 2007/08 breeding season: Pelsaert Island 18–20 November; Wooded Island 23 November; Morley Island 24 November 2007.
- 2008/09 breeding season: Pelsaert Island 21–24 December; Wooded Island 14 December; Morley Island 15 December 2008.
- 2013/14 breeding season: Pelsaert Island 12 to 13 November; Morley Island 7 December; Wooded Island 8 December 2013.
- 2014/15 breeding season: Pelsaert Island 24–27 November Morley 17 November; Wooded 18 November 2014.

Prior to 2006, estimates were based on the total area of mangroves calculated from aerial photographs, with quadrats containing unsuitable habitat included in calculations. From 2006, areas used in calculations were the estimated area of live mangroves, with quadrats containing unsuitable habitat (i.e. dead mangroves or no mangroves) omitted from calculations.

Areas of live mangroves were estimated using polygons over aerial photographs taken during each survey using fixed-wing aircraft and aerial photographs overlaid on Google Earth using the Landgate (Western Australian Land Information Authority) application 'Locate'.

RESULTS

Estimates and standard errors of the number of breeding pairs and, for later years, the estimated number of nests in use, for each colony, and the summed means for islands with more than one colony, are presented in Table 2 and Figure 2.

Estimated numbers of breeding pairs have fluctuated within and between islands. Numbers of breeding pairs on Pelsaert

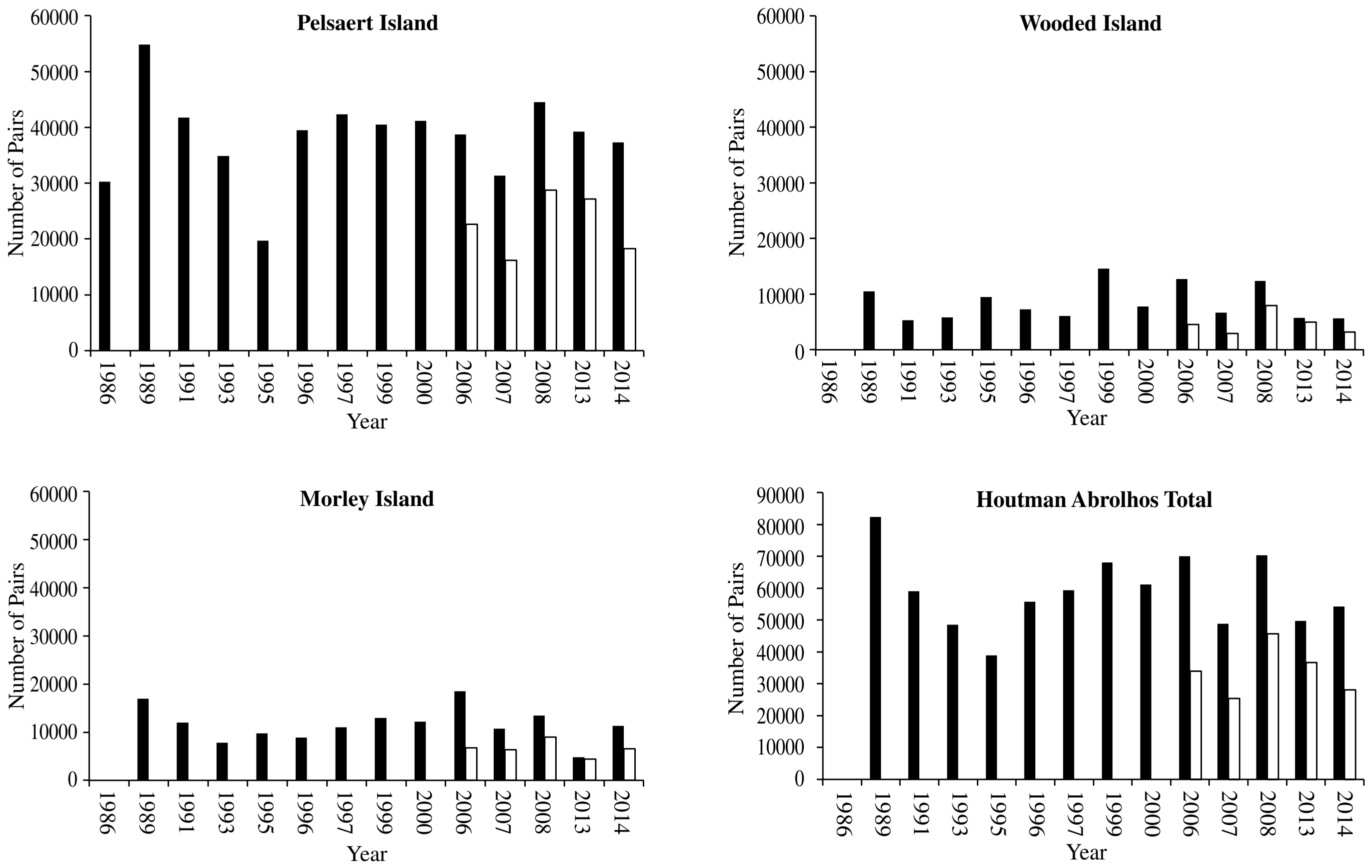

Figure 2: *Summed means of estimated number of breeding pairs of Lesser Noddies for each island and for the whole Australian population. Hollow bars are nests in use at the time of the estimate.*

Island, which has the largest colonies, were relatively stable between 1991 and 2006, were lower in 2006, but recovered in 2007. In 2013 numbers were again close to the levels estimated between 1991 and 2006, but the 2014 estimate was lower. On Wooded Island, there have been major fluctuations with estimates between 1989 and 1997 being between *c.* 5300 and *c.* 9500 breeding pairs. However, in 1999 the estimate was greater than 14 000 but was only *c.* 3200 in 2000. Estimates in 2006 and 2008 were greater than 12 000 pairs; however, in 2007 the estimate was only *c.* 6700. Morley Island has also shown fluctuations with greater than 16 000 estimated in 1989 and 2006, but lower estimates in other years. The 2013 estimate of *c.* 4 700 pairs was the lowest on record.

For the Houtman Abrolhos population, numbers have been relatively stable, but with some years of lower estimates. The estimates in 2006/07 and 2007/08 breeding seasons were low, but similar to 1993. The estimates for 2013/14 and 2014/15 seasons are comparable with those of 1993 and 2007, but this was the first time that two consecutive yearly estimates are low.

Table 3 shows estimated percent of dead and defoliated mangroves in selected years between 1964 and 2014. Although there has been an overall loss of breeding habitat, the percentage of mangrove habitat for each colony that was affected by defoliation or dieback from 1964–2012 (Table 2) has varied, with recovery in some colonies, notably the mangroves in colonies 1 and 2 on Pelsaert Island, which are the largest Lesser Noddy breeding colonies.

DISCUSSION

Trends in numbers of breeding pairs

The 2013/14 and 2014/15 season estimates are some of the lowest on record (Table 2). Whether these numbers reflect a long or short-term decline is unclear. A number of factors may be contributing to population decline, including mangrove dieback (Surman and Nicholson 2009a), ENSO-driven reproductive failures (Surman and Nicholson 2009b) and longer term changes in local oceanography (Surman *et al.* 2012). Surman *et al.* (2012) found that there were significant oceanographic influences upon the timing of breeding of Lesser Noddies, with later breeding between 2001 and 2010 when compared with the previous ten years (1991–2000).

It is notable that the proportion of nests in use on Wooded and Morley Islands was higher in 2013 (counts made 7 and 8 December) than on Pelsaert (counts made 12–13 November).

Change in the extent of useable mangrove

A potential threat to the Houtman Abrolhos Lesser Noddy population is mangrove dieback and defoliation. On Wooded Island the long-term presence of a Pied Cormorant *Phalacrocorax varius* colony in the mangroves has caused extensive mangrove defoliation. Whilst the Pied Cormorant colony shifts location from one year to the next, the foliage of regenerating mangroves is too dense for Lesser Noddies to

Table 2

Estimated number of breeding pairs of Lesser Noddies for Pelsaert, Wooded and Morley Islands, Houtman Abrolhos, Western Australia. Estimates, where calculated, are ± Standard Error (SE). Figures without SE are counts of small colonies. 'Total, all quadrats' is the estimate for Pelsaert Island using all quadrats on that island.

Island	Colony	Year 1989	1991	1993	1995	1996	1997	1999	2000	2006	2007	2008	2013	2014
Pelsaert	**1**	28 900 ± 2325	26 420 ± 3000	20 110 ± 2040	19 700 ± 2260	21 021 ± 2290	24 034 ± 2498	26 036 ± 2457	25 049 ± 2488	14 007 ± 1744	12 377 ± 1474	13 628 ± 2283	15 832 ± 2330	14 357 ± 2178
	2	21 615 ± 2660	14 015 ± 8580	14 760 ± 1385	19 100 ± 1635	18 440 ± 1592	18 310 ± 1921	14 490 ± 1352	16 073 ± 1543	21 366 ± 2001	13 745 ± 1479	14 093 ± 1577	11 759 ± 1491	10 025 ± 1133
	3	0	0	0	0	0	0	0	0	0	0	1940 ±385	0	0
	4	0	16	0	0	0	0	0	0	0	0	2130 ±470	0	0
	5	3480 ± 1090	1 220 ± 660	0	0	0	0	0	0	3193 ± 1051	5245 ± 1003	9043 ± 1320	11 636 ± 1452	7561 ± 995
	6	115 ± 80	86 ± 40	0	0	0	0	0	0	0	0	61	0	3
	7	0	0											
	8	0	0	0	0	0	0	0	0	192	0	3578 ± 337	0	0
	South end	0	0	0	0	40	25	25	0	0	0	0	0	0
Summed means		**54 110**	**41 761**	**34 870**	**38 800**	**39 461**	**42 369**	**40 526**	**41 121**	**38 758**	**31 367**	**45 187**	**39 227**	**31 943**
Total (all quadrats)					**40 821 ± 2997**	**41 061 ±2900**	**43 385 ± 3245**	**40 109 ± 2658**	**41 305 ± 2717**	**42 972 ± 3697**	**32 633 ± 2506**	**45 644 ± 3904**	**40 758 ± 3637**	**31 792 ± 933**
Wooded	**Main**	**6875**	**5345**	**6325**	**8769 ± 1353**	**5906 ±1055**	**5237 ± 928**	**12 837 ± 1859**	**6829 ± 882**	**12 712 ± 2162**	**6709 ± 1300**	**12 936 ± 3798**	**5572 ± 1011**	**5179 ± 985**
	Small				**680**	**1405**	**840**	**1790**	**980**	**0**	**0**	**0**	**200**	**515**
summed means		**6875**	**5345**	**6325**	**9449**	**7311**	**6077**	**14 627**	**7809**	**12 712**	**6709**	**12 396**	**5772**	**5694**
Morley	**Main**	**16 375 ± 2455**	**11 750 ± 2440**	**7665 ± 1535**	**9790 ± 1812**	**8931 ± 1470**	**10 992 ± 1621**	**12 979 ± 1851**	**12 208 ± 1453**	**18 532 ± 2355**	**10 758 ± 1912**	**13 502 ± 2416**	**4713 ± 621**	**11 327 ± 1631**
	Small				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**50**	**20**
summed means		**16 375**	**11 750**	**7655**	**9790**	**8931**	**10 992**	**12979**	**12 208**	**18 532**	**10 758**	**13 502**	**4763**	**11 347**
Houtman Abrolhos														
Summed means		**77 360**	**58 856**	**48 850**	**58 039**	**55 703**	**59 438**	**68 132**	**61 138**	**63 678**	**48 834**	**71 085**	**49 762**	**50 271**

Table 3

The total mangrove area (m^2) and percentage of total mangrove habitat for each colony that was affected by defoliation or dieback from 1964-2014. Data estimated from aerial photographs obtained from Landgate (1964 – 2006, 2012), fixed wing aircraft (2007-2008), and a remote drone (2014). Pied Cormorant colony area (PC, % of total mangrove habitat) on Wooded Island is also included. Data for mangrove habitat on non-Lesser Noddy breeding islands included for comparison.

Island	Colony	Area (m^2)	Year 1964	1978	1982	1987	1998	2004	2006	2007	2008	2012	2014
Pelsaert	1	16 215	1.4	0.0	0.0	0.0	6.1	4.7	6.5	7.6	7.6	0.9	0.9
	2	12 214	2.4	0.0	0.0	0.0	5.8	13.2	9.8	12.6	12.6	4.6	4.6
	3	3 010	9.2	–	9.9	12.4	11.7	8.7	11.0	6.0	5.3	3.5	3.5
	4	1 783	8.1	–	10.1	0.0	1.2	0.0	3.4	0.0	0.0	0.0	0.0
	5	12 193	11.4	–	10.2	20.7	4.6	2.6	2.4	0.7	0.7	5.5	10.6
	6	1 520	4.8	–	9.2	6.3	6.3	39.2	35.2	11.1	9.2	9.2	9.0
	8	3 965	–	–	58.9	43.2	–	4.5	–	–	3.8	3.4	25.6
Wooded		10 168	12.3	–	10.3	9.2	5.7	18.4	18.5	19.5	10.7	1.7	7.6
	PC		14.0		12.3	13.9	13.2	6.4	6.9	16.4	0.0	7.3	12.8
Morley		11 968	34.0	–	7.1	2.9	2.5	39.6	35.0	46.9	39.3	33.0	30.0
Serventy		2 140					0.0	7.0	0.0				
Burnett		5 540					1.9	5.2	7.0				
Post Office		7 300					1.7	6.1	7.8				
Newman		4 220					0.9	27.1	18.9				

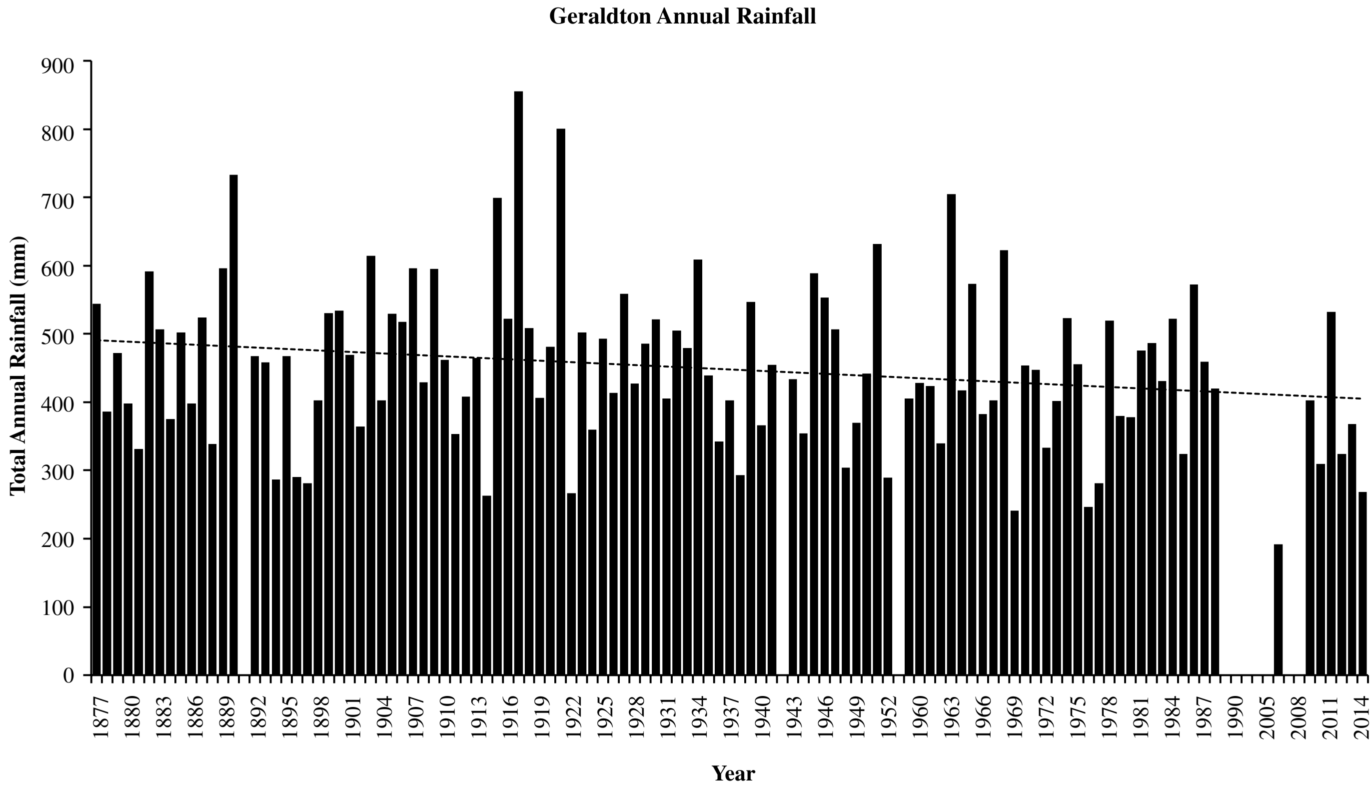

Figure 3: *Annual rainfall at Geraldton from 1877 with linear trendline. Years with incomplete data are omitted. Data from the Australian Bureau of Meteorology.*

recolonise for many years. On most islands, and some areas on Wooded Island, mangrove dieback cannot be attributed to the Pied Cormorant colony.

Table 3 shows that mangrove decline is, to some extent, cyclic. Two hypotheses may explain these changes. Firstly, Lesser Noddy nesting leads to increased nutrient levels from guano deposition; the subsequent defoliation causes the birds to nest elsewhere until the area recovers. This was observed on Pelsaert Island when in 1991/92 Lesser Noddies abandoned Colony 5 (when 20.7% of the mangrove there was defoliated) for 15 years until their return in the 2006/07 season to completely regenerated mangroves (0.7% dieback, Table 3).

Secondly, declining regional rainfall may lead to less flushing of both salt and nutrients from mangrove areas. Rainfall at the closest long-term station, Geraldton (60 km E, Figure 3), shows such a decline in line with much of SW Western Australia. Lower rainfall may explain mangrove decline in part, noting that decline has also occurred on close-by islands where Lesser Noddies do not breed (Table 2).

Mangrove dieback and death has been particularly severe on Morley Island. Biota (2005) noted that when Grey Mangroves exist at the extremes of their physiological tolerance, changes in nutrient level through reduced tidal flushing or sediment build-up often results in mangrove dieback. At the Houtman Abrolhos the trigger for this on Lesser Noddy breeding islands appears to be at least partly due to the build-up of guano excreted by the Lesser Noddy, and the ability of defoliated areas to recover is determined by the levels of tidal flushing.

Observed and predicted sea-level change may adversely impact mangroves at the Houtman Abrolhos. Since 1990, sea levels in SW Western Australia have risen at a faster rate (9 mm/y^{-1}) than elsewhere in Australia resulting in an average 160 millimetres rise in sea levels (Church and White 2011; Steffen and Hughes 2013). Predicted rates of increase by century end (500–1000 mm, NTF 2011) will presumably lead to further coastal erosion and loss of mangrove habitat. The three breeding islands are protected from winter storms by a coral reef and lagoon to the west, but not to the prevailing summer strong southerly winds.

Oceanographic effects

Long-term oceanographic variability is known to have negatively impacted both timing of breeding and reproductive success in the Lesser Noddy and other seabird species at the Houtman Abrolhos and further afield (Dunlop *et al*. 2002; Surman *et al*. 2012). ENSO events in 1997, 2002 and 2004 led to delayed onset of breeding and near catastrophic breeding failures in Lesser Noddies, Brown Noddies *Anous stolidus* and Sooty Terns *Onychoprion fuscatus*, and in very low breeding participation in the Wedge-tailed Shearwater *Ardenna pacifica* (Surman *et al*. 2012).

The strong link between ENSO events and breeding failures in seabirds appears to be decoupling with poor breeding seasons being also observed in non-ENSO years (Surman 1998; Surman and Nicholson 2009b). It would appear that the environmental trigger for the arrival of prey, perhaps as a result of a delayed autumn sea surface temperate (SST) peak (Caputi *et al*. 2009), has shifted and has led to consistently later breeding. Whilst the resident Lesser Noddy was found to be the most resilient to change of four species studied (Wedge-tailed Shearwater, Sooty Tern, Brown Noddy and Lesser Noddy - Surman *et al*. 2012) the cumulative impact of consecutive poor breeding seasons may inevitably lead to a reduction in the numbers of young entering the breeding pool.

Movement between islands

Changes in population sizes at various islands or colonies may be in part the result of movement of Lesser Noddies between mangrove areas. Wooded and Morley islands are situated very close to each other in the Easter Group, with the distance between the colonies (*c*. 600 m) being less than the distance between colonies 2 and 5 on Pelsaert (*c*. 3 km, Figure 1). Pelsaert Island colonies, however, are a minimum of 27 kilometres south of those on Wooded and Morley Islands. On Pelsaert Island, new small colonies of Lesser Noddies were established in some years and abandoned later (Table 1). The two major colonies on Pelsaert Island (1 and 2, Figure 1) have been occupied continuously since 1989, however smaller colonies (3 – 8) have only contained breeding birds in some years. Whilst Lesser Noddies are generally site-faithful (Surman and Wooller 1995), several birds banded at Colony 2 on Pelsaert Island have been observed nesting at Colony 5, three kilometres distant.

Conservation status of the Lesser Noddy (Houtman Abrolhos)

Lesser Noddies have been reported on islands at Ashmore Reef in small numbers (<120) in 2009 and 2010 and four were recorded nesting there in April 2010 (Clark *et al*. 2011). Houtman Abrolhos Lesser Noddies disperse during the non-breeding period across waters from Cape Leeuwin to North West Cape (Surman, unpublished geolocator data). This was confirmed recently when Lesser Noddies were observed roosting at night on Bernier Island, Shark Bay (Colleen Sims, *pers. comm.*). Lesser Noddies have also been reported occasionally at various places along the SW coast, usually associated with storm fronts (Higgins and Davies 1996). These records suggest that the only significant breeding colonies in the eastern Indian Ocean occurs at the Houtman Abrolhos.

Garnett *et al*. (2011), using IUCN Red List categories and criteria version 3.1 (IUCN 2001) evaluated the Australian subspecies of the Lesser Noddy as Endangered B2ab(iii,v). This requires that the Area of Occupancy (AOO) be less than 500 square kilometres and that it is severely fragmented or known to exist at no more than five locations and that there be a continuing decline in area, extent and/or quality of habitat and number of mature individuals. The AOO is *c*. four hectares, being the area of the colonial breeding mangroves (there are other small mangrove forests in the Houtman Abrolhos that are not used by Lesser Noddies for breeding; however, the total area of these is less than the area used in recent decades) and the subspecies breeds in three locations. However, data presented in Figure 2 and Table 2 indicates that there is not a 'continuing decline' in the number of mature individuals. It is unclear whether there is a 'continuing decline' in the 'area, extent and/or quality of habitat' (the mangroves) although mangrove dieback is persisting at several sites.

The Lesser Noddy (Houtman Abrolhos) meets *Vulnerable* under criterion D2, having a very restricted AOO and fewer than five locations and plausible threats (mangrove decline, sea surface temperature changes leading to changes in food availability, sea level rise) such that it is capable of becoming *Critically Endangered* within a very short time period. Therefore, whether to evaluate as *Endangered* or *Vulnerable* may depend on how precautionary an assessor decides to be.

ACKNOWLEDGEMENTS

We particularly thank John Blyth, Anthony Desmond, Tony Docherty, Lisa Nicholson, Shae Surman and Paul Warnock for their assistance in the field. Transport was kindly provided by the crews of *Hero*, *Reef Seeker*, and the Department of Fisheries (DoF) patrol vessels *PV Houtman* and *PV Chalmers*. We thank the Western Australian Department of Parks and Wildlife and the DoF for permission to conduct research at the islands (under Regulation 23 Licence BB003360). The DoF Saville-Kent Centre, M. Davidson, B. Humphries and J. Macfarlane of Chimera Pearls kindly provided accommodation. This research was in part funded by the Parks and Wildlife-managed project 'Back from the Brink', with funding provided through the Northern Agricultural Catchments Council from State and Commonwealth funds.

REFERENCES

Biota (2005). 'Yannarie Salt Project Mangrove and Coastal Ecosystem Study: Baseline Ecological Assessment'. Report for Straits Salt Pty. Ltd.

Burbidge, A. A. and Fuller, P. J. (1989). Numbers of breeding seabirds on Pelsaert Island, Houtman Abrolhos, Western Australia. *Corella* **13**: 57–61.

Burbidge, A. A. and Fuller, P. J. (2004). Numbers of non-burrowing breeding seabirds of the Houtman Abrolhos: 1991–1993 and 1999**.** *Corella* **28**: 96–103.

Caputi, N., de Lestang, S., Feng, M. and Pearce, A. F. (2009). Seasonal variation in the long-term warming trend in water temperature off the Western Australian coast. *Marine and Freshwater Research* **60**: 129–139.

Church, J. A. and White, N. J. (2011). Sea-level rise from the late 19th to the early 21st century. Surveys in Geophysics doi: 10.1007/S1072-011-9119-1.

Clark, R. H., Carter, M., Swann, G. and Thomson, J. (2011). The status of breeding seabirds and herons at Ashmore Reef, off the Kimberley coast, Australia. *Journal of the Royal Society of Western Australia* **94**: 365–376.

Dunlop, J. N., Long, P., Stejskal, I. and Surman, C. A. (2002). Inter-annual variations in breeding participation at four western Australian colonies of the Wedge-tailed Shearwater *Puffinus pacificus*. *Marine Ornithology* **30** (1): 13–18.

Fuller, P. J., Burbidge, A. A. and Owens, R. (1994). Breeding seabirds of the Houtman Abrolhos, Western Australia: 1991–1993. *Corella* **18**: 97–113.

Garnett, S. T., Szabo, J. K. and Dutson, G. (2011). 'The action plan for Australian birds 2010'. (CSIRO Publishing: Collingwood.)

Higgins, P. J. and Davies, S. J. J. F. (eds) 1996 Handbook of Australian, New Zealand and Antarctic Birds. Volume 3. Snipe to Pigeons. (Oxford University Press, Melbourne.)

IUCN (2001). IUCN Red List categories and criteria, version 3.1. IUCN Species Survival omission. (IUCN, Gland, Switzerland and Cambridge, UK)

Steffen, W. and Hughes, L. (2013). The Critical Decade 2013: Climate change science, risks and response. Commonwealth of Australia (Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education).

Surman, C. A. (1997). 'A comparative study of the breeding and feeding biology of three sympatric tropical terns on the Houtman Abrolhos, Western Australia'. PhD Thesis, Murdoch University, Western Australia.

Surman, C. A. (1998). Seabird breeding schedules at the Pelsaert Group of islands, Houtman Abrolhos, Western Australia between 1993 and 1998. *Records of the Western Australian Museum* **19**: 209–215.

Surman, C. A. and Nicholson, L. W. (2009a). 'Trends in population and habitat status in the threatened Lesser Noddy *Anous tenuirostris melanops* at the Houtman Abrolhos'. Report to the Department of Environment and Conservation, Western Australia.

Surman, C. A. and Nicholson, L. W. (2009b). The good, the bad and the ugly: ENSO driven oceanographic variability and its influence on seabird diet and reproductive performance at the Houtman Abrolhos, Eastern Indian Ocean. *Marine Ornithology* **37**: 129–138.

Surman, C. A. and Wooller, R. D. (1995). The breeding biology of the Lesser Noddy on Pelsaert Island, Western Australia. *Emu* **95**: 47–53.

Surman, C. A., Nicholson, L. W. and Santora, J. A. (2012). Effects of climate variability on breeding phenology and performance of tropical seabirds in the eastern Indian Ocean. *Marine Ecology Progress Series* **454**: 147–157