

# Torresian Imperial Pigeon *Ducula spilorrhoa* monitoring, population trends and species suitability as an indicator of environmental changes

Nigel Brothers<sup>1</sup> and Catherine Bone

<sup>1</sup>Corresponding author: 178 South Arm Drive, Wonga Beach QLD 4873  
Email: brothersbone@yahoo.com.au

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A comparison of historical counts and those made during this study, of the Torresian Imperial Pigeon *Ducula spilorrhoa* nesting populations of the northernmost region of Australia's Great Barrier Reef suggest that numbers have remained stable or increased slightly over the last 20 years. The reliability of monitoring *D. spilorrhoa* abundance accurately has been confirmed and indicates that ongoing monitoring could be an important contribution to understanding climate change impacts on the species and on two highly vulnerable and important vegetation types, upon which this species depends. As a result of this study the number of nesting colonies for which counts have been undertaken in this region has been expanded from 11 to 26, and six of these have provided the first indications of trends in abundance.

## INTRODUCTION

The majority of Torresian Imperial Pigeons *Ducula spilorrhoa* in Australia occupy nesting islands between September and April along 750 kilometres of the north-east coast between Low Isles and Portland Roads (Fig. 1). The *D. spilorrhoa* nesting colony site preference of relatively small offshore islands, dependence on adjacent rainforests for food, synchronous nesting, and daily routine of return make it feasible (Thorsborne *et al.* 1988) to census this quite abundant species with a high degree of accuracy. There are few, if any other tropical rainforest-dependent species for which a large proportion of the population can be counted. *D. spilorrhoa* that breed in Australia spend their non-breeding season in the forests of Papua New Guinea (PNG).

Although information has been collected in the past on the distribution and abundance of *D. spilorrhoa* in this region (King 1990) in addition to two island populations having been regularly counted (Thorsborne *et al.* 1988), there has been no attempt made to conduct a more comprehensive and systematic census. For many nesting localities, only estimates exist and the most recent count for the majority of islands are now over 20 years old. To date there have been no data from which indications of population trends can be obtained. It is increasingly important that "species for which reliable historical records are available, and whose biology suggests may be sensitive indicators of climate change, need to be identified and monitored", (Hughes 2003, p. 438). It is therefore regrettable that there are limited *D. spilorrhoa* historical records because this species is a potential 'sensitive indicator' for the following reasons:

- *D. spilorrhoa* is considered to be a 'true' frugivore (McConkey *et al.* 2004) and an excellent seed disperser in tropical rainforests and Price (2006) suggests that the ability of plants to adapt to the rapid climate changes that will be brought about by global warming will depend critically on the maintenance of sizable populations of frugivores.

- *D. spilorrhoa* populations may also be able to ameliorate the effects of fragmentation in tropical rainforests by dispersing seeds from one area of rainforest to another. Fragmentation caused by land clearing for agriculture and urban development is a widespread feature of the forests within the foraging range of *D. spilorrhoa*. With nesting colonies on islands distributed along virtually the entire length of the Great Barrier Reef, *D. spilorrhoa* have access to a significant amount of the highly fragmented and often remnant tropical rainforest habitat on which they are dependent for food.
- This species is dependent on the Great Barrier Reef island mangrove environment, which is a breeding habitat that has been identified as highly vulnerable to various predicted consequences of global warming (Lovelock and Ellison 2007). The majority of the islands occupied by *D. spilorrhoa* for breeding are classified as 'low wooded islands' (Steers 1937) consisting of mangrove forests usually growing in a lagoon environment 0.36 metres below mean sea level, making them highly vulnerable to sea level rise (Lovelock and Ellison 2007). Furthermore, species of mangroves from the family *Rhizophoraceae* which dominate most of the island nesting habitats cannot be coppiced, have no epicormic buds from which to re-sprout after canopy damage and so are likely to be particularly adversely affected by enhanced cyclonic frequency or intensity (Lovelock and Ellison 2007).

Population monitoring may assist in providing some measure of human impact (other than climate change) on *D. spilorrhoa* here in Australia as well as in PNG where they spend the non-breeding season. Abrahams *et al.* (1995) point out that although a common species, the nesting behaviour of this species makes it vulnerable to human disturbance and therefore a certain level of understanding about population status and trends of colonies is important in the face of continual expansion of human visitation in the nesting region.

The need for updating knowledge about the distribution and abundance of this species has been highlighted by this study and an attempt made to initiate this process.



**Figure 1.** Map of Cape York showing islands where *D. spilorrhoa* were counted (in black) using the regular count method and other islands, which were surveyed for the species (in red).

## MATERIALS AND METHODS

A bird count methodology identical to that described by King (1990) and very similar to Thorsborne *et al.* (1988) was used. Counting at each site commenced at 1530 hours and all birds returning to the island in each 15-minute period until darkness (prior to which the majority of birds had returned) were recorded (Table 1). In accordance with monthly abundance trends revealed by Thorsborne *et al.* (1988) an objective was to confine counts to within the optimum period of the breeding season as much as possible, within the constraints imposed by the large latitudinal distribution and high total number of

nesting localities. Counts were made between 9 November and 28 December 2008. The peak of the breeding cycle relates to the highest quality and quantity of fruit (of *Lauraceae* species in particular) (Crome 1975). Confining counts to the two months selected takes this factor into account.

All counts were made from the deck of a 17 metre stationary vessel, from an elevation of 1–2 metres above sea level. The vessel was anchored in the position judged to be optimum to give sufficient clear visibility of all pigeons returning to that locality and at a distance from where they could be accurately counted. Access to the optimum count position was constrained at certain

**TABLE 1**  
*D. spilorrhoa* counts at nesting islands of far north-eastern Australia in November and December 2008. CR = Count Reliability 1 (low) – 5 (high)

Date	Locality	CR	Position Lat.(S)/Long.(E)	Count Time Interval (15 minutes)															Count Total
				1530	1545	1600	1615	1630	1645	1700	1715	1730	1745	1800	1815	1830	1845	1900	
9-Nov	Low Isles-Woody	4	16° 22.83'/145° 33.78'	54	87	175	614	1706	2651	4053	4513	3600	2375	1519	1014	281	3	22 685	
10-Nov	Hope Is. East	5	15° 43.794'/145° 27.300'	18	341	519	643	885	1561	1435	1786	1387	1112	602	191	66		10 546	
11-Nov	Hope Is. East	5	15° 43.500'/145° 27.400'	30	62	123	211	461	800	1330	1510	1696	1698	1319	776	389		10 405	
14-Nov	Three Isles	1	15° 06.507'/145° 24.967'	7	2	26	43	77	125	422	597	1303	1175	1058	408			5243	
16-Nov	Bewick Is.	5	14° 25.808'/144° 48.244'	8	9	14	29	55	116	238	312	256	253	142	31	24	1	1487	
17-Nov	Barrow Islets	5	14° 20.492'/144° 38.698'	6	24	20	60	118	118	90	88	79	29	54	41	15		742	
18-Nov	Pipon Is.	3	14° 07.155'/144° 30.575'	258	410	900	1997	2445	2792	2934	2550	1857	1330	1190	980			19 659	
20-Nov	Burkitt Is.	4	13° 56.555'/143° 44.788'	0	0	21	9	29	82	150	451	2014	1846	4107	3162	1125		12 977	
21-Nov	Hannah Is.	5	13° 51.896'/143° 42.686'	33	111	219	409	994	1698	3843	4640	4717	3690	4352	1839	865	18	27 428	
22-Nov	Wilkie Is.	1	13° 46.521'/143° 38.032'	21	39	44	59	114	347	1542	3692	5873						11 731	
23-Nov	Wilkie Is.	1	13° 46.521'/143° 38.032'	20	32	46												98	
3-Dec	Wilkie Is.	3	13° 46.766'/143° 38.080'	76	82	89	107	278	593	1437	2709	4114	5429	5245	2590	1688		24 437	
5-Dec	Wilkie Is.	5	(200m NW from prev.)	42	39	70	139	173	315	800	2133	3480	5120	6540	7000	5260	3016	778	34 905
24-Nov	Night Is.	4	13° 10.917'/143° 34.353'	99	295	822	2093	3475	4850	9034	11034	10650	8116	4129	3188	560		58 343	
25-Nov	Chapman Is.	5	12° 53.614'/143° 53.890'	6	30	66	58	56	42	35	30	13	28	12	2	2		380	
27-Nov	Rocky Is.	4	12° 35.544'/143° 24.512'	220	181	270	117	174	119	154	241	526	835	694	659	514		4704	
29-Nov	Lowrie Is.	4	13° 16.220'/143° 35.945'	28	36	50	120	232	515	1183	2236	3187	3259	2712	1155	789	67	15 566	
30-Nov	Morris Is.	5	13° 29.696'/143° 43.118'	0	7	19	12	49	184	373	540	506	407	273	158	269	1	2798	
1-Dec	Fife Is.	5	13° 39.210'/143° 42.893'	2	3	1	8	17	20	52	107	117	74	72	14	5		492	
2-Dec	Hay Is.	5	13° 39.969'/143° 41.202'	120	147	235	384	818	1924	4367	5580	6880	8630	6460	5490	4650	3210	720	49 615
12-Dec	Noble Is.	5	14° 30.039'/144° 45.586'	0	0	0	1	3	8	46	66	73	52	17	22	2		290	
13-Dec	Howick Is.	5	14° 29.797'/144° 57.015'	0	0	0	0	0	0	0	0	0	1	3	2	2		8	
14-Dec	Turtle Is. group	3	14° 44.249'/154° 11.607'	24	98	179	196	202	231	390	899	1592	3161	3732	2971	1784	1086		16 544
15-Dec	Nymph Is.	5	14° 39.066'/145° 14.776'	3	1	8	7	28	50	64	106	156	66	213	127	81	4		1014
27-Dec	Low Wooded Is.	4	15° 05.547'/145° 22.289'	316	377	440	875	1909	3452	4338	7420	11 280	11 255	9930	3992	1999	829	73	58 485
28-Dec	Hope Is. West	5	15° 45.030'/145° 26.303'	183	259	608	1166	2490	4980	7250	9070	7890	5420	4800	4923	4413	719		54 171

TABLE 2

Islands at which the conventional count method of determining *D. spilorrhoea* abundance was not used, but where presence or absence of nesting *D. spilorrhoea* was ascertained.

Date	Location	Count	Notes
19-Nov + 7-10 Dec	Stanley Is.	0	
28-Nov	Restoration Rock	96	~ 100 prs nesting
28-Nov	Sherrard Is.	28	Total nest count 31
29-Nov	Binstead Is.	~ 1000-1200 pairs	Nesting observed
7-Dec	Eden Reef	0	
7-Dec	Wharton Reef	0	
7-10 Dec	Flinders Is.	0	
8-Dec	Clack Is.	1	Single bird dead on beach. Extensive suitable nesting habitat
8-Dec	King Is.	0	Extensive suitable nesting habitat
13-Dec	Sand Is.	0	
13-Dec	Newton Is.	3 (landed briefly)	Extensive suitable nesting habitat
14-Dec	Houghton Is.	0	Extensive suitable nesting habitat
14-Dec	Coquet Is.	0	Suitable nesting habitat
14-Dec	Petheridge Is. north	0	
14-Dec	Petheridge Is. south	0	
16-26 Dec	Lizard Is.	see notes	Small nos. foraging only. ~ 20 prs nesting on islet adjacent to resort.
29-Dec	Snapper Is.	18	Small numbers visiting - suspect in transit to/from Low Isles.

localities by extensive shallow water and the prevailing wind direction and strength at the time. The best counting position was dictated by the orientation of the island and its distance from the mainland forest feeding site(s), as this determines the return flight path of the birds. The selection of position also had to consider the potential for differentiating a bird's ultimate destination where birds from several nesting islands were on a coinciding flight path. The latitude and longitude positions of each count site were documented to allow for the most directly comparable counts in the future. Each colony counted was rated on a scale of one to five to indicate relative count accuracy and as an assessment of whether a future count of equivalent accuracy could be made here. One person counted from each side of the vessel so that the count area was divided into two distinct sectors. Apart from those localities where in excess of 20 000 pairs occurred, it was possible to accurately keep abreast of incoming numbers while counting every individual bird. However, it was sometimes necessary to count birds in groups of around ten when peak return rates exceeded the ability to count birds individually. The accuracy of this technique of estimating individual small flock size, was regularly verified outside count periods. Hand-held tally counters were used to assist in keeping an accurate tally of birds during each 15-minute count. Count site selection was aimed at preventing any reliance on the use of binoculars, but this was not always possible. Leica 7X42B binoculars were used when necessary.

At some islands visited where low numbers of *D. spilorrhoea* occurred using the standard count method was not warranted. In such cases a total nest count was made where practicable. At 22 islands (Table 1) the standard count method was applied and at a further 17 islands (Table 2) an assessment of pigeon abundance, including 'no pigeon occurrence' was made. For comparative purposes some repeat counts and counts from previous nesting seasons at two sites have been also presented (Table 3).

Indications of trends in population size and breeding distribution were obtained by a comparison between historical

counts (Crome 1975; Thorsborne *et al.* 1988; King 1990) and counts made in this study (Table 4).

## RESULTS

A total of 39 islands were surveyed for *D. spilorrhoea* breeding activity. The northernmost locality was Rocky Island near Portland Roads, and the southernmost was Low Isles (Woody Island) east of Port Douglas, a distance apart of approximately 500 kilometres (Fig. 1). Out of the 39 islands, *D. spilorrhoea* nesting did not occur on 13 islands, six of which were considered to have suitable, extensive habitat. Of the islands on which *D. spilorrhoea* were found to be breeding, counts of birds were made at all but three, for which a breeding population size estimate was made. Table 1 provides the results of counts at each locality, and Table 2 lists all other localities surveyed together with comments in relation to the presence of *D. spilorrhoea* and suitable nesting habitat. Table 3 provides additional count information from previous breeding seasons at three sites and includes the 2008 count.

In total, 398 074 birds (representing this number of breeding pairs) were counted at 22 breeding islands at which the standard count method was applied. The largest single count at any locality was 58 485 birds. Examining the breakdown of each count into 15-minute intervals (Table 1) indicates that about 70 per cent of birds usually return to the island between 1700 and 1800 hours. The greatest number of birds within a 15-minute period was 11 280, which is a return rate of just over 12 birds per second.

Counts repeated at the same locality within several days (Tables 1 and 3) indicate the potential reliability of the count method, with a small difference (as little as 1–2%) between each count total.

Of the six islands at which new counts were made for which comparable historical count data exist (Table 4) there is a population increase indicated at 4 localities, and a possible slight decline is indicated at the other two localities (Fig. 2).

TABLE 3

*D. spilorrhoea* counts at selected island nesting sites in the years 2004, 2005 and 2007. CR = Count Reliability 1 (low) – 5 (high)

Date	CR	Locality	Position Lat.(S)/Long.(E)	Count Time Interval (15 minutes)												Count Total	
				1600	1615	1630	1645	1700	1715	1730	1745	1800	1815	1830	1845		1900
25-Dec-04	4	Low Isles (Woody Is.)	16° 22.929'/145° 33.824'	93	170	219	578	1423	2745	3269	3331	3331	1784	2183	949	58	20 133
2-Dec-05	4	Low Isles (Woody Is.)	16° 22.929'/145° 33.824'	115	295	1091	2224	3006	4018	4244	2366	1506	1093	431	101		20 490
9-Dec-07	4	Low Isles (Woody Is.)	16° 22.929'/145° 33.824'	58	87	237	205	1168	2213	3152	3776	3376	2473	1447	938	15	19 441
27-Dec-04	5	Hope Isles East	15° 43.794'/145° 27.300'	15	103	324	1067	1771	1946	1817	1207	484	496	458	123	10	9848
2-Jan-05	5	Hope Isles East	15° 43.794'/145° 27.300'	206	291	677	757	862	1298	1211	1391	1192	1107	612	378	111	10 093
28-Dec-04	2	Hope Isles West	15° 44.803'/145° 26.254'	462	791	1187	2181	3373	3986	2704	4143	1960	2076	363			23 904

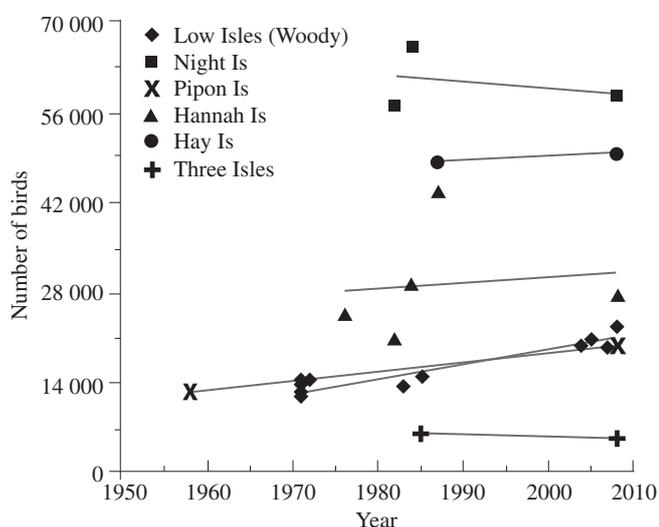


Figure 2. *D. spilorrhoea* population trends on six islands which have been derived from historical counts and counts from the current study.

DISCUSSION

Count methodology considerations

Crome (1975) and Thorsborne *et al.* (1988) both demonstrated from repeat counts on consecutive or near days, that the count method gives a consistent result. Figures provided in Table 3 and those for Hope Isles East in Table 1 further demonstrate the potential accuracy of the count method. Therefore, if counts are taken at a similar stage of the breeding cycle (Thorsborne *et al.* 1988) counts at the same site from different years should be comparable. It has been the assumption that provided counts of returning birds are not made too late in the breeding season (by which time fledglings are entering the adult population), they represent the number of breeding pairs present (Crome 1975; Thorsborne *et al.* 1988). This is because one member of each pair remains at the nest, while the other forages on the mainland. There do not appear to have been any attempts made to validate this assumption that each bird always represents a breeding pair and there are obvious difficulties in doing this apart from the

matter of disturbance. However, during the course of the 2008 count, each site was considered for its suitability for such an evaluation. Fife and Chapman islands were found to be most fitting to the necessary criteria. For the most meaningful or accurate interpretation of the data in the future, it would be desirable that this evaluation be undertaken. The count of Rocky Island for instance is suspected to have contained a significant number of birds that were not actually using this island as a nesting site but instead as an overnight roost. A general impression when ashore at some localities was of considerably fewer nests present than the number inferred from counts of returning birds. However if this were the case, less consistent consecutive day counts of the same locality would be expected.

For the purpose of meaningful or accurate population trend monitoring, sites need to be carefully selected. Important factors are the likelihood of prevailing weather conditions allowing access to the best count position, and the extent to which the flight path of birds can alter seasonally. Few localities offered optimum count positions as just one factor can interfere with the ability to make an accurate count. This point is illustrated further by the counts of 3 and 5 December at Wilkie Island (Table 1). The count position on 5 December was only 200 metres farther to the north-west than that of the previous count. While little difference exists in the numbers of birds counted in each location up until 1800 hours, the count difference after 1800 hours became substantial. This is because just 200-metre variation in position greatly reduced the visibility of one sector of birds still returning in large numbers during low light conditions before darkness fell. The result in this instance was a decrease in the total count of around 10 468 (from a total of 34 905), which renders such a count meaningless. In contrast, just a 1–2 per cent difference between counts is achievable when the count position and site is ideal (Hope Isles East, Tables 1 and 3). Of all the localities at which counts were undertaken only the following sites were considered optimum for most accurate long-term trends and abundance monitoring: Hope Isles (East), Hannah Island, Chapman Island, Lowrie Island, Morris Island, Fife Island, Hay Island, Nymph Island, Low Isles (Woody) although at this last site, island orientation and proximity to an extensive area of mainland may compromise the reliability of count comparisons due to the potential for wide variations in

TABLE 4

Comparable counts of *D. spilorrhoa* abundance on six islands taken from historical records and the current study.

Year	Bird Count	Location	Date	Source
1971	13 180	Low Is.	22-Jan	Crome (1975)
1971	13 750	Low Is.	23-Jan	Crome (1975)
1971	12 650	Low Is.	25-Oct	Crome (1975)
1971	11 780	Low Is.	23-Nov	Crome (1975)
1972	14 470	Low Is.	31-Oct	Crome (1975)
1983	13 605	Low Is.	27-Nov	Bahrtd and Smyth in Thorsborne et al. (1988)
1985	15 037	Low Is.	6-Dec	Cornelius in Thorsborne et al. (1988)
2004	20 133	Low Is.	25-Dec	Current study
2005	20 490	Low Is.	2-Dec	Current study
2007	19 441	Low Is.	9-Dec	Current study
2008	22 685	Low Is.	9-Nov	Current study
1982	56 928	Night Is.	10-Nov	King 1990
1984	66 110	Night Is.	17-Nov	Zigterman in King (1990)
2008	58 343	Night Is.	24-Nov	Current study
1958	12 400	Pipon Is.	18-Jan	Warham in King (1990)
2008	19 659	Pipon Is.	18-Nov	Current study
1976	24 564	Hannah Is.	28-Nov	Limpus in King (1990)
1982	21 026	Hannah Is.	9-Nov	King (1990)
1984	29 263	Hannah Is.	16-Nov	King (1990)
1987	43 811	Hannah Is.	21-Nov	Zigterman in King (1990)
2008	27 428	Hannah Is.	21-Nov	Current study
1987	48 361	Hay Is.	22-Nov	Zigterman in King (1990)
2008	49 615	Hay Is.	2-Dec	Current study
1985	6181	Three Isles	22-Nov	King (1990)
2008	5243	Three Isles	14-Nov	Current study

flight path, thus altering the optimum count location. Few, if any of the largest colonies (i.e. in excess of around 20 000) allow for the highest level of count accuracy simply due to the rapid rate of incoming birds to be counted.

The question of site tenacity, and whether migration is occurring to any great extent or with any consistency between colonies does need to be explored if trends are to be based on counts at selected sites only, particularly if the population estimates of six potentially quite large sites now absent of birds, were indeed accurate. There remains the intriguing question of whether these birds actually shifted to another site, died out or were never in fact present.

#### Population trends

There are currently six islands for which past counts could be used to determine trends in population size over time. Based on these counts, by comparing those made in the early to mid 1980's with those made around 20 years later, numbers appear to have remained stable or increased slightly. A comparison of historic counts (Crome 1975) with more recent counts supports the trend of an increasing population at Low Isles. At Night Island, the later of two counts in the 1980s recorded 8000 more pairs than the 2008 count. Considering the severity and extent of nesting habitat damage believed to be caused by severe tropical cyclone Ingrid in 2005 (Queensland Government 2005), a decline in pigeon numbers here is considered likely. Further decline in abundance is likely to occur over many more nesting seasons because a large proportion of nest sites are now exposed to weather impacts and higher levels of predator disturbance due to nesting habitat destruction. Night Island is among the

largest of all *D. spilorrhoa* colonies so this is significant. The same impact was also seen at nearby Lowrie Island.

*D. spilorrhoa* populations at Hay Island were very similar (around 49 000) at both count intervals and they were also similar at Three Isles (around 6000). For Hannah Island the 2008 count at around 27 000 was close to each of three earlier counts, although the fourth historical count record in 1987 was around 16 000 more birds. An increase in abundance at only this site and of this magnitude since the previous count just three years earlier seems unlikely, which is at least partly supported by the population trend data presented by Thorsborne *et al.* (1988). At Low Isles (Woody Island) counts over several years in the early 1980s, (in Thorsborne *et al.* 1988) were consistently around 12 000 to 15 000 whereas in 2004, 2005 and 2007 (Tables 1 and 3), numbers were consistently higher at around 20 000, suggesting that numbers here have increased.

Published historical counts exist (King 1990) for another five islands (Hannibal, Boydong, Cairncross, Beasley/Baird and Two Isles), which unfortunately could not be covered as planned in the 2008 census. It would be of benefit to obtain current comparative count data for these localities and to obtain actual counts at more colonies in this region to replace the historical estimates, which evidence suggests might be grossly inaccurate.

#### Population size estimates and their discrepancies

Either there have been significant changes in the distribution and abundance of *D. spilorrhoa* in the past 20 years or the historical record (King 1990) contains inaccuracies, particularly where estimates rather than counts were made. Of particular note

are six islands (Clack, King, Petheridge, Newton, Houghton and Coquet islands) that had been assigned an estimated medium (1000–10 000 pairs) population size, whereas in 2008 birds were found not to be using any of these islands for breeding. In contrast and without exception, the 2008 survey of localities for which the historical population size was based on an actual count, corroborated the earlier figures. Historical records of *D. spilorrhoea* abundance in the region contained actual counts at 12 of 95 islands listed as being colonies. The 2008 count has increased this list of counted colonies to 27. The fact that the six colonies with historical population estimates of medium size colonies (1000–10 000 pairs) revealed no evidence of being occupied, indicates the importance of obtaining actual count data wherever possible. This also serves to illustrate that population status based on such wide ranging size criteria is undesirable because large errors can arise. Neither the Key Sites nor the Coastal Bird Atlas Databases of the Department of Environment and Natural Resources, Brisbane (S. Taylor, pers. comm.) contain records that could confirm breeding at these sites. However, considering the prevalence of suitable nesting habitat on all these islands, knowledge about the species nesting distribution in the past, and the methodology for constructing the estimates of population size, it is perhaps understandable that in the absence of actual observations, birds were presumed to breed at these sites. Compared to the usual distance offshore from adjacent rainforest foraging habitat of most nesting islands, there would appear to be considerably less rainforest immediately adjacent to islands in this region and Pipon Island is the main one being used for nesting. The return flight path to Pipon Island is distinctly from the south and south-east and indicates that the more extensive rainforests well to the south were being used for feeding. As a result, with prevailing south-east winds, and extensive shallow water limiting access to a close anchorage on the northern side, a comprehensive count is not easy to obtain at Pipon Island. A count of around 7000 more birds in 2008 compared to the 1958 count (in King 1990) could be due entirely to such difficulties (as described in the previous section of this paper).

Unfortunately it is not possible to discount the possibility that there has been a disappearance of birds from certain islands in the past 20 years. Traditional nesting sites of other colonial nesting species such as cormorants, gulls and terns can be vacated for varying numbers of nesting seasons, presumably as a means of better utilising a shifting food source or to reduce parasite impacts on nestlings. An attempt was made to verify the records in Crome (1975) that are likely to have been the source of King's (1990) population estimates for at least three of the six islands in question. However, Crome's source, a charter boat operator Mr. Simms is now deceased. Another four islands claimed by this same source to be large colonies have proven to be accurate. For a number of other islands with a past estimated figure of abundance (King 1990), major discrepancies between these and current count figures were found. For example at Wilkie Island with 3000 to 10 000 estimated, 24 437 were counted. At Noble Island 2000 to 10 000 were estimated and 290 were counted. At Low Wooded Island 2000 to 10,000 were estimated and 58 485 were counted in this study.

It is recommended that population monitoring be continued at nesting islands for which a high level of count accuracy can be achieved. At nesting islands where only estimates exist,

counts should be obtained, particularly in the northernmost sector of the nesting range. Further examination of any existing, unpublished count data is required in order to investigate the apparent disappearance of certain colonies. Correlating counts of birds with actual numbers of occupied nests would enable more precise quantification of population sizes. Genetics studies may help to ascertain site fidelity in this species.

A study of feeding patterns and behaviour at selected sites across the species breeding range is also needed. Both GPS and satellite methodology are viable for this species and tracking studies would give a greater understanding of foraging ecology and the movement of birds outside the breeding season. Such work would also refine ways to use the species for monitoring change in its two vulnerable key habitats and help conserve the species.

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