

SURVEY OF FAIRY TERN *STERNA NEREIS EXSUL* IN NEW CALEDONIA

NICOLAS BARRÉ¹, MARLEEN BALING², NATHALIE BAILLON³, AUBERT LE BOUTEILLER¹, PIERRE BACHY¹,
VIVIEN CHARTENDRAULT¹ & JÉRÔME SPAGGIARI^{1,4}

¹*Société Calédonienne d'Ornithologie, BP 3135, 98846 Nouméa, Nouvelle-Calédonie (belairbarre@hotmail.fr)*

²*Pacific Invasives Initiative, IUCN Invasive Species Specialist Group,
The University of Auckland, Private Bag 92019, Auckland, New Zealand*

³*Direction du Développement Economique et de l'Environnement, BP 41, 98860 Koné, Nouvelle-Calédonie*

⁴*Conservation International, 69 avenue Koenig, Rivière Salée, 98846 Nouméa, Nouvelle-Calédonie*

Received 1 May 2011, accepted 25 February 2012

SUMMARY

BARRÉ, N., BALING, M., BAILLON, N., LE BOUTEILLER, A., BACHY, P., CHARTENDRAULT, V. & SPAGGIARI, J. 2012. Survey of Fairy Tern *Sterna nereis exsul* in New Caledonia. *Marine Ornithology* 40: 31–38.

The threatened New Caledonian Fairy Tern *Sterna nereis exsul* is known to breed in the southern lagoon of New Caledonia's mainland, Grande Terre (approximately 40 breeding individuals), and on the Chesterfield Atoll (40–80 individuals). Field surveys conducted between 2005 and 2008 revealed two new significant breeding sites, including three islets in the northwestern lagoon (48–248 breeding individuals) and one in the eastern lagoon (40 individuals). Mean (95% CI) clutch size per nest for the northwestern nesting colonies was 1.54 ± 0.07 ($n = 181$). Annual breeding success (ratio of the number of fledglings to number of eggs laid) was very low: 0.27 ± 0.08 for 2006, 0.07 ± 0.04 for 2007 and 0.02 ± 0.03 for 2008. Breeding failed occasionally due to avian predation, but regularly due to adverse weather conditions, which destroyed most or all nests for two successive years (2007 and 2008). The Fairy Tern nesting colonies at the southern lagoon, especially around Nouméa, are frequently disturbed by human visitation to breeding islets. We support the development and implementation of a Fairy Tern Conservation Strategy to address all identified threats affecting this vulnerable species throughout its range. This includes adaptive management of breeding sites and the establishment of long-term monitoring to measure the efficiency of conservation actions.

Key words: seabird, Pacific island, breeding sites, breeding chronology, breeding success, threats, conservation, *Sterna nereis*

INTRODUCTION

The Fairy Tern *Sterna nereis* has three recognised subspecies that differ in their morphology, genetic relatedness and geographic distribution (Higgins & Davis 1996, Baling & Brunton 2005, Baling 2008). Their distribution spans Australia (*S. n. nereis*), New Zealand (*S. n. davisae*) and New Caledonia (*S. n. exsul*). The species (including juveniles) has also been observed in one of Samoa's islands and may be breeding there (Tarburton 2001, Watling 2001). With the exception of the Australian population (less than 5 000 breeding adults), the size of the other two populations is extremely low, with about 200–400 breeding individuals in New Caledonia, and 30–40 individuals in New Zealand (Ferreira *et al.* 2005, BirdLife International 2011). The IUCN Red List listed this species as “Near Threatened” in 1988, then “Vulnerable” in 1994, and as “At Low Risk/ Least Concern” in 2000. It was recently upgraded again to “Vulnerable” (IUCN 2010, BirdLife International 2011), owing to recent decline in eastern Australia.

Previous breeding sites of the New Caledonian Fairy Tern were known only on islets in the southern lagoon of the mainland island, Grande Terre (Pandolfi-Benoît & Bretagnolle 2002, Baling *et al.* 2008, Baling *et al.* 2009), and one in the Chesterfield Atoll (Rancurel 1976, de Naurois & Rancurel, 1978, Bourne *et al.* 2005). There are no published records of nesting Fairy Terns from the Loyalty Islands (Barré *et al.* 2006) or other parts of the lagoons. Recent observations of Fairy Terns at East Diamond Islet (Australia's Coral Sea Islands Territory), and also approximately 480 km southeast in the Swain Reefs National Park, Australia (Great Barrier Reef World

Heritage Area), may extend the distribution of this subspecies far to the northwest and west, respectively, of New Caledonia (Carter & Mustoe 2007, Andrew McDougall pers. comm., July 2009). From these records, the overall population size from these known breeding sites totalled a maximum of 80 individuals, assuming no double-counting; much less than the 200–400 breeding birds estimated by BirdLife International (2011, following F. Hannecart per. Pandolfi 1999 and Barré *et al.* 2007). This leads to the hypothesis that other breeding sites may exist in New Caledonia. This study reviews previous surveys, reports the discovery of new breeding sites in the northwestern and the eastern lagoons of New Caledonia, and re-evaluates the status of the New Caledonian Fairy Tern.

METHODS

Study sites

New Caledonia is located around 21°30'S, 165°30'E in the southwest Pacific Ocean, approximately 1 200 km east of Queensland, Australia, and 1 500 km northwest of New Zealand. The main island, Grande Terre, is mountainous, and is surrounded by a large lagoon lined by a coral reef and dotted with small, low-lying coral or sandy islets (Fig. 1). The lagoon is generally divided into different zones (south, north, east and west) relative to Grande Terre. The southern lagoon has been designated a World Heritage Site since 2008, and is part of the Southern Lagoon Important Bird Area (IBA) (Spaggiari *et al.* 2007b). Here, islets are particularly dense south of Nouméa, and 23 out of more than 50 islets are located at the southern tip.

Islets are also numerous in the northwestern lagoon in the Poum, Paagoumène and Koumac areas (30 islets), and 16 of these islets are included in the Northwestern Lagoon IBA (Spaggiari *et al.* 2007b). About 10 coral islets are spread out along the east coast of Grande Terre. In addition, two large atolls surrounded by low-lying coral islets are part of the New Caledonian region: the Chesterfield-Bampton-Belona reef 550 km northwest of Nouméa, and the Entrecasteaux reef, located at the northern tip of the main coral reef. Both areas are also IBAs (Spaggiari *et al.* 2007b).

The northwestern lagoon in the Paagoumène area has three islets used by Fairy Terns for nesting: Îlot Double, Île Yan'dagouet and Îlot Pouh (Fig. 1). Like most lagoon islets, these three oval-shaped islets are composed of sand and coral, with sizes of 2–3 ha. The interior is covered with a dense and short (6 m height) bushy forest while the periphery is open and sandy. The beach of the northern tip is larger than other parts of the island beach. Among coastal bird species, the Pacific Reef-Heron *Egretta sacra*, Silver Gull *Larus novaehollandiae*, as well as different species of waders are commonly present at these sites. One pair each of the Beach Thick-knee *Esacus magnirostris* and Osprey *Pandion haliaetus* breed on Îlot Double. The Peregrine Falcon *Falco peregrinus* and the Swamp Harrier *Circus approximans* are occasionally seen on the islets.

Monitoring

Our surveys were conducted in the north, east and south zones of the lagoon. We landed a boat at each site when possible and when

justified by presence of birds. At each breeding site, birds were initially observed from a vantage point to locate the positions of nests and chicks. Then one to three people counted the eggs and chicks by carefully walking side by side, 2 m apart, through the colony. This usually took 1–3 min depending of the size of the colony. Before leaving the colony site, the observers checked that flying breeders returned to their nest—which they did in less than 1 min.

Southern and eastern lagoons: Before 2005, occasional visits were made to selected islets in the southern lagoon at different periods of the year. After 2005, visits were more frequent, with data provided to the *Société Calédonienne d'Ornithologie* (SCO) coordinator of the study. In 2008 a survey was conducted from July to September 2008 on 19 selected islets within the lagoon (Fig. 1), based partly on previous observations by Bell (1998). Islets were visited one to three times by a team of four or five people. In addition, occasional visits occurred during the rest of the year.

Northern lagoon: In 2005, a marine bird survey was conducted in the northern lagoon (Baudat-Franceschi 2006). The discovery of Fairy Tern nesting colonies prompted more detailed observations at the Paagoumène islets in the northwest: Îlot Pouh, Îlot Yan'dagouet, and Îlot Double. Monthly visits were made to the three islets during the Fairy Tern breeding seasons (May–September) from 2006 to 2008. This involved a boat and two to four people. The monthly interval allowed sufficient time to separate different egg-laying times and avoided double counts of egg clutches and chicks (based on 22 days of incubation, Ferreira *et al.* 2005). Any external events

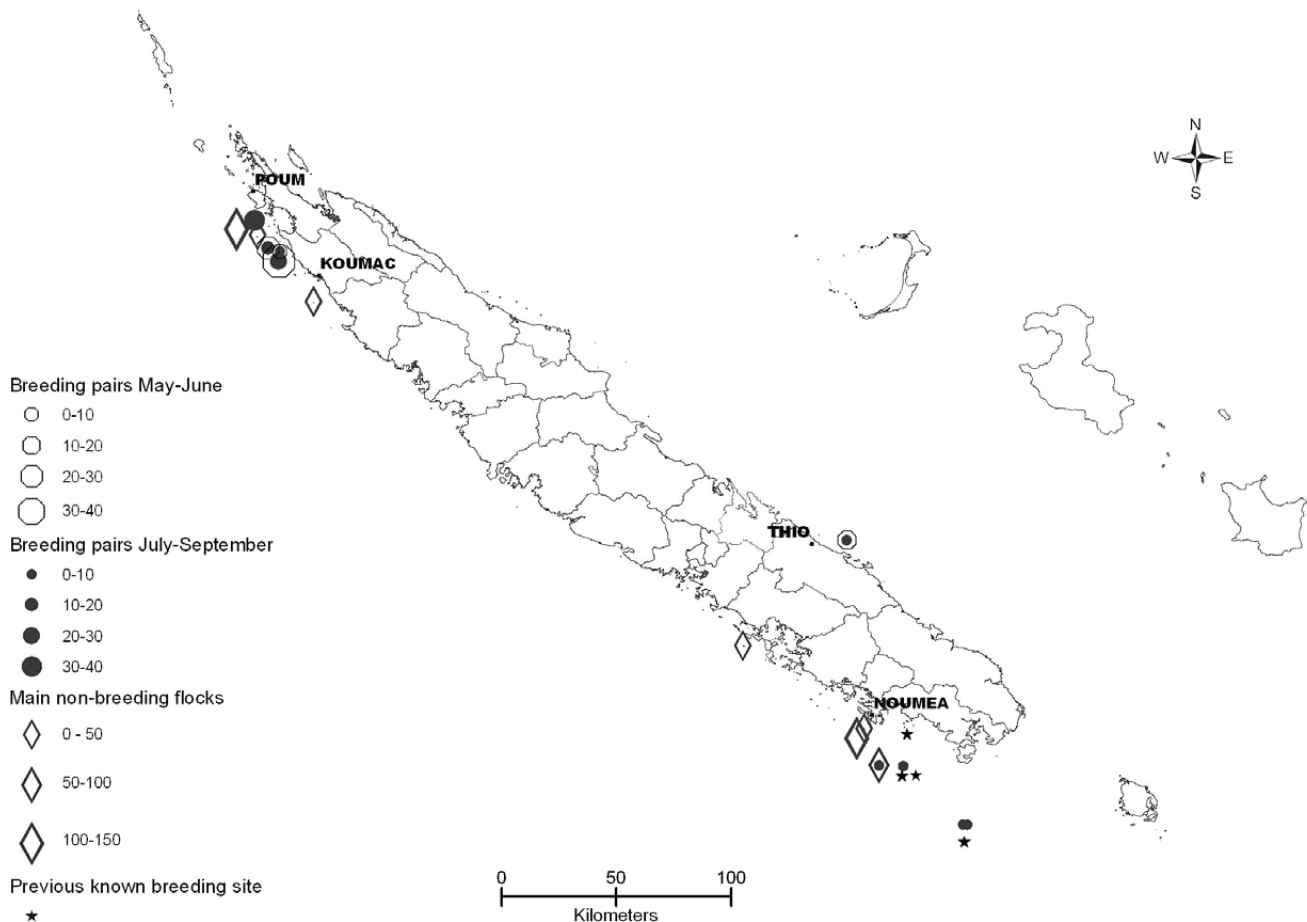


Fig. 1. Distribution of the New Caledonian Fairy Tern in islets around Grand Terre, New Caledonia.

(weather conditions, human disturbance and predation) during the observation period were also taken into account.

Occasional visits were made to other surrounding islets. A complementary survey for Fairy Tern was conducted between June and August in 2007 and 2008 on most of the islets of the Kaala Gomen, Koumac and Paagoumène area, including Deverd, Kendec, Rat, Ti ambouène, Nana, Tangadiou, Magone and Carrey islets.

Data analysis

Fairy Tern seasonal population numbers and distribution are described according to zones: southern lagoon, eastern lagoon, northern lagoon, Chesterfield islands and Entrecasteaux reefs. Historical data were available for the southern lagoon and the Chesterfield islands (Hitchcock 1959, Hill *et al.* 1988, Higgins & Davies 1996, Carter & Mustoe 2007). Previous field survey reports and other literature concerning tern distribution were collated for comparison and review.

New Caledonia Fairy Terns are not banded; therefore, estimates of breeding adults were made by survey counts of adults in breeding plumage and the number of nests found. We assumed that all observed breeding adults would have nested at least once in 2006 and 2007 during normal meteorological conditions.

First observed egg-laying dates, number of eggs and nesting colony locations were recorded and tabulated from 2006 to 2008. A linear regression was plotted for the first observed laying dates for each zone with latitude. Egg-laying dates were also divided between early (May–June) and late (July–September) in the breeding season. Early and late egg-laying dates were determined from the peak breeding time of our data and that of Baling *et al.* (2009).

The number of adult Fairy Tern pairs and nests, mean clutch-sizes and reproductive success for the three Paagoumène islets were recorded for three consecutive years (2006–2008). The mean clutch size and 95% confidence intervals (CI) were calculated as the average number of eggs or young chicks in a nest. Data from all three islets were combined to produce mean clutch sizes for 2006 and 2007. Data from 2008 were omitted due to the potential influence of adverse weather on final clutch size value for that year. The success of reproduction was evaluated as the ratio of the number of fledglings to the number of eggs laid (Ferreira *et al.* 2005). This was also combined and calculated for each breeding year of our data and of the data from Baling *et al.* (2009).

RESULTS

Observations during the inter-breeding period

After the breeding season, New Caledonian Fairy Terns rapidly lose their breeding plumage and gather in flocks on lagoon islets and cays south of Nouméa (Fig. 1). On Îlot Amédée 84 birds in non-breeding plumage were seen in January 1998, 55 in January 2001, 65 in December 2004 (plus 12 on Îlot Maître and seven on Îlot Canard). In November 2005, 13 immatures or adults in non-breeding plumage were recorded on Îlot N'Do, at the southern tip of the southern lagoon. During January and February 2007, a total of 295 Fairy Terns in immature/non-breeding plumage were counted on Îlot Amédée (105), Îlot Goéland (155) and Îlot Maître (35). In February 2008, a total of 150 “small white terns” (including several Little Terns, *S. albifrons*

sinensis) were observed on Îlot Ténia, 60 km north of Nouméa, in the Boulouparis commune (Y.M. Anne, pers. comm.), an area poorly surveyed during previous years. Every year, a few individuals were also observed in the estuary of the Dumbéa River, between Nouméa and Boulouparis. In the northern lagoon, there were about 150 Fairy Terns counted in 2005 (Baudat-Franceschi 2006).

Observations during the breeding period

Southern lagoon

Layard & Layard (1882) indicated the presence of Fairy Tern breeding colonies close to Nouméa on “rocky islets near Anse Vata,” presumably Îlot Canard. The species has also been known to breed in large numbers just off Nouméa between 1960 and 1980 (Hannecart, de Naurois & Rancurel, pers. comm., quoted by Pandolfi-Benoît & Bretagnolle, 2002). These last authors reported a colony of 20 birds in the southern lagoon in 1992, and then an absence of the species from the area between 1993 and 1996. Three pairs were sighted at two sites in 1997, and up to seven small colonies were noted in 1998. There were only three nesting colonies found in September 1999. The distribution of the Fairy Tern nesting colonies on these islets between the 1990s and 2000s was not listed exhaustively, but Îlot Kouaré and Îlot Redika also supported small colonies (Spaggiari *et al.* 2007a).

On 9 August 2003, a colony of 18 adult Fairy Terns in breeding plumage and one nest containing eggs was discovered at a little dead coral bank, Îlot Kaé (Bachy, unpublished data). Baling *et al.* (2008, 2009) surveyed 22 islets in the southern lagoon between June to October 2004 and found nesting colonies of 12 nests on Îlot Kaé and 10 on Îlot Atire. First eggs were laid mid-July, last clutches mid-September, with the peak of egg-laying in 2004 in mid-September. Mean clutch size was 1.43 eggs per nest (Baling *et al.* 2009), with an overall fledgling success per egg of 0.24 ± 0.03 ($n = 33$).

The nest colony on Îlot Kaé was observed again in the following year; however, Îlot Atire was not surveyed. In 2005, three adult pairs laid eggs in mid-August to beginning of September on Îlot Kaé. Both islets were visited in July, August, September 2006 and 2007, but no nesting birds were found. During the July–September 2008 survey, no nesting birds were established on Îlot Atire or Îlot Kaé, but 17 pairs were observed on four other islets: Îlot Ua (2), Îlot Uatio (3), Îlot Amédée (3), and Île Mbé (9). Egg-laying periods (Table 1) were between mid-August (Îlot Amédée) and mid-September (Îlot Mbé).

Eastern lagoon

The eastern zones of the lagoon were surveyed in 2005 (Baudat-Franceschi 2006), and no colonies were found on four islets off Poindimié or on two islets off Ponérihouen. In 2005 and 2008, a visit to Menyuru islet following a bird survey (28 August 2008) on islets in the Thio area (Fig. 1) yielded a count of 19 adults. There were at least nine pairs nesting on eggs, a pair digging a nest, and a 10-day-old chick. The Melanesian owner of the islet had made anecdotal observations of adult birds in higher numbers with young birds at various stages of development two weeks earlier.

Northern lagoon

The first evidence of potential breeding in the northern lagoon was documented in August 2005, with three adult Fairy Terns each

feeding early fledglings on Îlot Carrey, northwest of Grande Terre (Baudat-Franceschi, 2006). On 8 May 2006 this was confirmed with the discovery of three adult pairs nesting on eggs on Îlot Double, south of Paagoumène (Fig. 1) (Baillon, unpublished data, 2006, Barré *et al.* 2007). No nesting colonies were seen on Deverd, Kendec, Rat, Ti ambouène, Nana, Tangadiou, Magone or Carrey islets between 2006 and 2008. Nesting colonies were present in the early breeding season on three Paagoumène islets: Îlot Pouh, Îlot Double and Îlot Yan'dagouet (Table 1). The maximum number of adults in breeding plumage (Table 2) and the estimated number of breeding pairs (Table 3) varied between years and islets.

There are one to four sub-colonies, usually within a short distance (40–100 m) of each other, every year on each of the three Paagoumène islets (Table 3). These sub-colonies consisted of from only a few up to 34 pairs of breeding adults with eggs (mainly two-egg clutches) or chicks. Nest site use within each islet was also highly variable between years. For example, the northwestern site Îlot Double was used intensively in 2007, whereas nests were spread out among other sites on other years. Nests were established on sand or dead coral, where vegetation is scarce, and often very close to the high tide line.

The first egg-laying attempt occurred in early May each year on all three islets (Fig. 2), with the peak of egg-laying between June and

July. This first laying attempt is one of the earliest recorded in our surveys (Table 1). There is a significant linear relationship between first observed egg-lay dates and latitude ($R^2 = 0.5425$, $P < 0.01$), with the northern colonies tending to have earlier observed laying dates than the southern ones (Fig. 3).

The overall mean clutch size was 1.54 ± 0.07 eggs per nest ($n = 181$), with 1.51 ± 0.11 ($n = 87$) in 2006 and 1.57 ± 0.10 ($n = 94$) in 2007. A high number of two-egg clutches was observed at the beginning of the breeding season at the colonies, but this number was later reduced, as subsequent nests had mainly one-egg clutches (Fig. 2).

Replacement nests were observed at the end of July 2007 and the beginning of July 2008, following heavy storms (29 June 2007, 18 May 2008 and 29 July 2008) that nearly destroyed all existing colonies (Fig. 2). After the storm in 2007, carrying up to 170 mm rainfall, only two chicks and seven fledglings had survived (as of 15 July 2007), out of the 66 nests counted in the Paagoumène islets. Later in July, courtship behaviour was observed on the islets, and 25 pairs subsequently re-nested.

TABLE 1
Period of Fairy Tern egg-laying attempts in the different areas in New Caledonia and number of nests found on each site

Location	Latitudes		Years	Laying periods; number of nests	
	Degree	UTM ($\times 1000$)		(May– June)	(July– Sept)
Southern lagoon	South of 22°21'				
Îlot Ua		7486	2008		2
Îlot Uatio		7486	2008		3
Îlot Amédée		7511	2006–08		3
Îlot Mbé		7511	2008		8
Eastern lagoon	21°45'				
Îlot Menyuru		7591	2008	20	10
Northern lagoon	20°50'				
Îlot Pouh		7732	2006–08	2–20	0–25
Îlot Double		7734	2006–08	0–72	1–12
Île Yan'dagouet		7738	2006–08	2–12	0–14
Sub-total (lagoons)			2006–08	24–124	27–77
Chesterfield islands	19°54'				
Passage		7788	2004	28	
Mouillage		7788	1976	20	
Sub-total (Chesterfield)				20–28	
Total			2004–08	44–152	27–77

TABLE 2
Maximum numbers of adult Fairy Terns in breeding plumage at three Paagoumène islets, New Caledonia, in between 2006 and 2008

Islet	Year; number of breeding adults (exact day/month)		
	2006	2007	2008
Îlot Double	100 (04/06)	60 (09/06)	20 (15/08)
Île Yan'dagouet	83 (04/06)	4 (15/07)	59 (07/06)
Îlot Pouh	30 (13/08)	65 (29/07)	139 (11/05)
All islands	185 (08/07)	107 (09/06)	195 (11/05)

TABLE 3
Number of nests (with eggs or chicks at nest less than 8 days old; early and late laying) on the different sub-colonies on three Paagoumène islets, New Caledonia, 2006 to 2008

Islet locations	2006	2007	2008	Total
Îlot Double				
Northeast	12	6	9	27
Northwest	0	34	0	34
Isthmus	18	0	0	18
South	43	7	3	53
Île Yan'dagouet				
North	6	2	15	23
East	0	0	10	10
South	5	0	1	6
Îlot Pouh				
North	3	15	0	18
West	0	8	0	8
Southwest	0	22	2	24
Total	87	94	40	221

A similar event occurred in 2008, in which only nine nests from a colony of 195 breeding adults at Îlot Yan'dagouet survived heavy rainfall (38.9 mm) and strong winds in May. Subsequent to this storm event, Fairy Tern courtship, copulation, scrape excavation and egg-laying behaviours were observed on Île Yan'dagouet. Overall, the success of reproduction of Fairy Terns in the northern lagoon was 0.27 ± 0.08 ($n = 133$) fledglings per egg in 2006, 0.07 ± 0.04 ($n = 148$) in 2007, and 0.02 ± 0.03 ($n = 105$) in 2008.

Chesterfield islands and Entrecasteaux reefs

Denham (quoted by Bourne *et al.* 2005) reported *Sternula nereis* nesting on Observatory Cay on middle Bellona reefs in September 1858. Rancurel (1973) recorded small bird flocks at Loop, Longue and Le Mouillage islets in June 1973, and young birds nearly flying on a sandy bank in September of the same year (Rancurel 1976). De Naurois & Rancurel (1978) observed about 20 nests of Fairy Tern with one to two eggs or chicks on 25 June 1976, but did not state the location of this colony. In October 1977, Condamin (1977) reported 12 Fairy Terns, some in breeding plumage, on a sandy bank between the islets of Le Mouillage. Four birds were also seen in the northern part of the atoll on Bampton in December 1989 (Kusser & Suprin 1990). Counts from a photograph taken by Guido Gay (pers. comm.) on the island of Le Passage (5 November 2004) showed 58 birds in non-breeding plumage and two juveniles. During a survey

at the Chesterfield Atoll between 12 and 23 June 2007 we counted 13 adults displaying courtship behaviour on the southeastern spit of Île Longue (18 June) and two on the east Passage Island (19 June). From these surveys, the Chesterfield population is considered small, estimated to be between 20 and 40 pairs.

At Entrecasteaux, two Fairy Terns were recorded on Surprise Island in December 1996 (Robinet *et al.* 1997), but this species was not present during visits in November 2001, December 2007 and 2008 (Bachy, unpublished data). Three individuals in breeding plumage were sighted, but not observed nesting, in January 2008 on Huon (Spaggiari, unpublished data).

Observed potential threats to the Fairy Tern

There is at least one known pair of Silver Gulls breeding at Île Yan'dagouet, and we observed Silver Gulls predated at least two nests during the 2007 and 2008 seasons (following adverse weather conditions). However, the Fairy Terns did not seem to show any aggression toward the gulls when they were in close proximity (generally fly-off behaviour). A Peregrine Falcon has been documented establishing at Île Yan'dagouet in July; upon our arrival, it was flushed from a dead branch of a *Casuarina* where there were remains of three Fairy Tern fledglings (8 July 2006).

We observed a high number of recreational boats or ships (>10) that often anchor and land on islets closest to the main town, Nouméa, southern lagoon, with an estimated yearly increase rate of 10% in human visitation to these islets (Le Bouteiller, pers. obs.). The less inhabited northern lagoon had lower public visitation rates than the southern lagoon, where only four boats were sighted over the last three years of surveys (32 visits). The visitors to the northern islets did not approach the existing tern colonies. However, some had dogs with them.

DISCUSSION

Population size and distribution

From 1998 to 2009 the cumulative count of non-breeding New Caledonian Fairy Terns in the southern lagoon varied from about 50 to 300. Overall, the actual population size may exceed the 400 individuals estimated for this subspecies (BirdLife International 2011). Non-breeding flocks were larger in the south (maximum 295 individuals) than the north (150 individuals), although breeding colonies were larger in the north (1–72 nests) than in the south (2–12). Birds may move between zones, but movement cannot be confirmed unless birds are banded for individual identification. Additionally, Fairy Tern counts during the non-breeding period may be biased because Fairy Terns are difficult to distinguish from non-breeding migratory Little Terns during the austral summer. In December and January, 30–45 non-breeding Little Terns arrive in New Caledonia, acquire their breeding plumage from February to March, and depart between April and May. Little Terns have never been recorded breeding in New Caledonia; therefore, misidentification of fledglings and inter-breeding have not occurred, as they have in Australia (Cox & Close 1997, Ross *et al.* 1999). During their stay in New Caledonia, Little Terns form mixed flocks with Fairy Terns on the Nouméa-Boulouparis islets (Barré & Bachy 2003; Barré *et al.* 2007). These mixed flocks were documented as “small terns” in some surveys. Flocks of non-breeding Little Tern have not been recorded in the northern parts of the country.

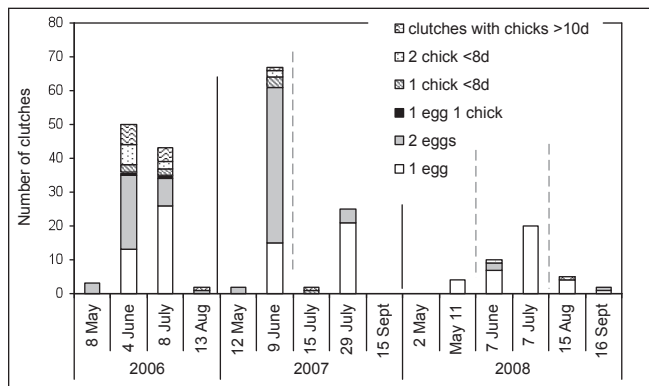


Fig. 2. Number of Fairy Tern eggs, chicks and fledglings on the Paagoumène islets, New Caledonia, 2006 to 2008. Dashed vertical lines indicate storms or catastrophic events.

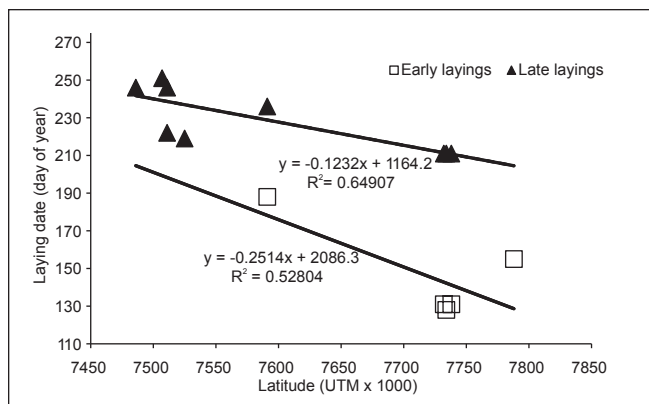


Fig. 3. Linear regression ($p < 0.001$) between first observed New Caledonian Fairy Tern egg-laying attempts and latitude, for early (May–June, open squares) and late (July–September, filled triangles) breeding seasons 2006 to 2008.

Chronology of breeding: one or two distinct populations?

The relationship between the start of egg-laying and latitude is consistent with findings of Hitchcock (1959) for other bird species, in which breeding tends to start later at higher latitudes (Baker 1938, Olsen & Marples 1993, Wanless *et al.* 2008). Our survey also recorded the earliest egg-laying attempt for this species, which is the beginning of May (c.f. end of August in Hitchcock 1959). Our surveys cannot explain whether this early date was due to the discovery of new breeding sites at lower latitudes (i.e. northwestern lagoon) or to other factors such as climatic conditions (Laaksonen *et al.* 2006, Reed *et al.* 2009). However, our three consecutive years of late egg-laying date records in the southern lagoon complements the 2004 season data from Baling *et al.* (2009). In this case, we assumed that the start dates for the northern colonies, at least in 2004, would have been similar.

Data suggest that there may be two separate egg-laying periods between the northern (May–June) and southern (July–September) breeding sites; however, more data, especially from identifiable individuals, is required to confirm this. We propose two hypotheses to explain such differences: (1) there are two sub-populations of New Caledonian Fairy Tern that have different breeding periods (i.e. northern and southern populations), or (2) New Caledonian Fairy Terns shift to different nesting sites (heading south) depending on the condition of their stages during the breeding season. The first hypothesis would imply that the two sub-populations do not overlap in breeding, and should therefore be considered distinct breeding populations. The second hypothesis, which is more likely, suggests asynchronous reproduction within the breeding season due to replacement clutches. This species is known to lay replacement clutches if an egg-laying attempt fails as a result of various detrimental external events (Parrish & Pulham 1995, Ferreira *et al.* 2005). We suspect that New Caledonian Fairy Terns in the north start egg-laying in May; if there is a catastrophic event leading to nest abandonment, different nesting sites may be used at the later dates. Therefore, nesting colonies in the southern lagoon may be second (July), or even third (September) laying attempts for the population. The movements between islets may explain variation in colony sizes and site use among breeding and non-breeding seasons (Pandolfi-Benoit & Bretagnolle 2002, Baling *et al.* 2008).

Reproductive success and threats

The rate of adult New Caledonia Fairy Terns breeding each year (100%) seems to be higher than for the New Zealand subspecies (43%; Ferreira *et al.* 2005), but reproductive success for both northern (27%, 7%, 4% annually) and southern (24%) lagoons was still relatively comparable to that of the endangered population in New Zealand (33%, 245 eggs produced 82 fledglings in 1996–2000; Ferreira *et al.* 2005). The breeding success of the New Zealand Fairy Tern is considered high for its small population size, and most likely to be attributed to intensive species management (Parrish & Honnor 1997, Hansen 2004, Taylor *et al.* 2004). The New Caledonia Fairy Tern production is also lower (northern lagoon: 40–94 observed nests produced 2–35 fledglings in this study; southern lagoon: 23 nests produced 14 fledglings; Baling *et al.* 2009) than that observed in the larger Australian population (50% nest success, >100 nests, in 1996–2000) by Paton & Patridge (2001). Accordingly, we suggest several possible factors that may influence production in the New Caledonian Fairy Tern: predation, weather and human influences.

Potential predators observed during our survey include both introduced and native predators. We do not know whether the level of impact of these animals was exacerbated by human activities. Avian predators identified in this study are Silver Gulls and Peregrine Falcons. Silver Gulls are a known predator of terns (Secomb 1994, Rose 2001, O'Connell & Beck 2003), and in New Caledonia we consider this species an opportunistic predator of vacated tern nests (pers. obs.). Other potential avian predators present are Swamp Harrier, Barn Owl *Tyto alba* and Pacific Reef Heron; however, there was no evidence of prey of these species. The main introduced mammal of concern is rats (*Rattus* spp.), which are well known to have devastating effects on seabirds' nesting success (Stapp 2002, Imber *et al.* 2003, Caut *et al.* 2008). Rats have been eradicated from most of the southern lagoon islets (Bell 1998) and are absent from known Fairy Tern breeding sites at the Chesterfield islands, Îlot Pouh and Île Yan'dagouet. *Rattus exulans* was the only rat species that occurred on Îlot Double (Baudat-Franceschi *et al.* 2008, 2009), but no evidence of clutches being eaten by rodents on this islet was seen during the three years of surveys.

Many examples in the literature have corroborated our observation that adverse weather conditions are a common cause of Fairy Tern breeding failure (Napier 1972, Hill *et al.* 1988, Pandolfi-Benoit & Bretagnolle 2002, Taylor *et al.* 2004). Anecdotal observations from our and other surveys (Pandolfi-Benoit & Bretagnolle 2002) suggest that weather conditions may also influence the New Caledonian Fairy Tern breeding colonies. The repeated failures in nesting attempts in seasons 2007 and 2008 were attributed to heavy storms with strong winds, high tides and heavy rain of the La Niña period. In contrast, Ferreira *et al.* (2005) did not see an effect of the Southern Oscillation Index (as a measure of adverse weather) on New Zealand Fairy Tern hatching rate. But the authors also acknowledged the possibility that the effect may be masked by more influential factors, such as the intense active management (Taylor *et al.* 2004), or other intrinsic factors, such as inbreeding, that cause a low hatching rate within this subspecies (Ferreira *et al.* 2005). Future surveys should incorporate recordings of environmental variables to enable a more accurate evaluation of the effect of climate on the population.

Human activity is a constant threat to tern nesting colonies (Hill *et al.* 1988, Robinet *et al.* 1997, Carney & Sydeman 1999, Pandolfi-Benoit & Bretagnolle 2002, Hansen 2004), and even when human are present as visitors (i.e. no direct mortality risk to the birds) they are still perceived by birds as potential predators. This perceived threat and its disturbance effects can cause a decline in nest success if there is insufficient distance between the colony and visitors (Beale & Monaghan 2004). Therefore, we should consider all human activity in close proximity to nesting sites as carrying a high risk of disturbance. Based on our observations of the New Caledonian Fairy Tern nesting colonies closest to the main town, Nouméa, sites in the southern lagoon have the highest risk of human disturbance, which may contribute to continual disturbance and desertion of nesting sites. Repeated human presence on these islets may also force terns to nest at alternative, suboptimal sites that are more exposed to strong winds and high tide levels.

Conservation measures

At the time of our surveys and data collection, several conservation measures had been initiated as part of a larger New Caledonia bird conservation plan. Most known breeding sites of the Fairy Tern

(except the islets closest to Nouméa) are in New Caledonia's IBA (Spaggiari *et al.* 2007b) and therefore will benefit from any future management actions. Additionally, SCO and BirdLife International (supported by the David and Lucile Packard Foundation) have established a seabird restoration programme for the northwestern islets, which complements a previous rodent eradication programme in the southern lagoon (Bell 1998). This current programme aims to eradicate rodents in the selected priority islets identified in 2008 (Baudat-Franceschi *et al.* 2008), which will benefit all seabird species including the Fairy Tern.

For the future management of the species, a New Caledonia Fairy Tern Conservation Strategy should be developed in which all the main issues identified in this study should be addressed. Baling (2008) and Baling *et al.* (2009) recommended the reduction or complete elimination of human disturbances by establishing seasonal public-access restrictions during the breeding seasons; we suggest May to September in the northern lagoon and mid-July to mid-October in the southern lagoon. Because nesting sites can differ between breeding seasons, sites will need to be identified before egg-laying. Once identified, protection of the nesting colony should be put in place for the whole islet or for an area of sufficient size around the colony on larger islands. This activity will only succeed if it includes committed provincial authorities and local stakeholders who will enforce this restriction.

The continual assessment of the population size and movement trends within New Caledonia could be determined by annual monitoring or a long-term scientific research programme. The bird-banding scheme for long-term individual identification established in New Zealand has provided much valuable data on population movements, breeding success and general life history (Baling 2008). We recommend a similar scheme and a population genetic study to investigate population distribution and movement as well as genetic relatedness between the northern and southern Fairy Tern colonies in New Caledonia.

CONCLUSION

The New Caledonian Fairy Tern population is currently between 130 and 270 breeding adults, with a maximum of 400 adults, with breeding sites primarily in the northern lagoon. Egg-laying later in the breeding season may indicate replacement clutches rather than separate populations. This vulnerable, threatened species is subject to adverse weather conditions, human disturbance and predators. Although the effects of climatic events cannot be completely eliminated, the known anthropogenic effects should be reduced as much as possible through an adaptive management programme. This means seasonal island restrictions for the public and continuation of the eradication of introduced mammals on important islets. Finally, the New Caledonian Fairy Tern could be flagship species, leading to management efforts for the conservation of this species that will directly benefit other seabird species in the area.

ACKNOWLEDGEMENTS

Part of this survey was conducted with the technical support of the *Direction de l'Environnement* of the South Province. We are particularly grateful to the chief of the *Service de la Mer*, C. Chevillon, and to the staff of this service; M. Mai, Y.M. Anne, F. Paul, P. Plichon and their crew, who spent time visiting the islets and provided useful information on the terns, and to J. Baudat-

Franceschi who drew the map. We are also very grateful to the North Province, especially J.J. Cassan of the *Service de l'Environnement*, who provided funding that allowed the identification of main breeding areas of the Fairy Tern in the north, and for his long-term support of our actions to save this species.

REFERENCES

- BALING, M. 2008. Conservation of the Fairy Tern (*Sternula nereis* spp.) via subspecies level management. *Endangered Species Update* 25 (3): 86–93.
- BALING, M. & BRUNTON, D.H. 2005. Conservation genetics of the New Zealand Fairy Tern (*Sterna nereis davisiae*). Auckland, NZ: Department of Conservation, New Zealand Government.
- BALING, M., BRUNTON, D.H. & JEFFRIES, D. 2008. Marine and coastal bird survey of islands in the Southern Lagoon, New Caledonia. *Notornis* 55: 111–113.
- BALING, M., JEFFRIES, D., BARRÉ, N. & BRUNTON, D.H. 2009. A survey of Fairy Tern (*Sterna nereis*) breeding colonies in the Southern Lagoon, New Caledonia. *Emu* 109: 57–61.
- BAKER, J.R. 1938. The relation between latitude and breeding season in birds. *Proceedings of the Zoological Society of London A* 108: 557–582.
- BARRÉ, N. & BACHY, P. 2003. Complément à la liste commentée des oiseaux de Nouvelle-Calédonie. *Alauda* 71 (1): 31–39.
- BARRÉ, N., VILLARD, P., MANCEAU, N., MENARD, C. & MONIMEAU, L. 2006. Les oiseaux de l'archipel des Loyauté (Nouvelle-Calédonie) : inventaire et éléments d'écologie et de biogéographie. *Terre et Vie* 61: 175–194.
- BARRÉ, N., BAUDAT-FRANCESCHI, J., SPAGGIARI, J., CHARTENDRAULT, V., BACHY, P., DESMOULINS, F. & GUHRING, J. 2007. Second complément à la liste des oiseaux de Nouvelle-Calédonie. *Alauda* 75: 129–144.
- BAUDAT-FRANCESCHI, J. 2006. Oiseaux marins et côtiers nicheurs en Province Nord. Evaluation des populations et enjeux de conservation. New Caledonia: Société Calédonienne d'Ornithologie, Province Nord de Nouvelle-Calédonie.
- BAUDAT-FRANCESCHI, J., CROMARTY, P., GOLDING C., LE BRETON, J., FAULGER D., CRANWELL S. & BOUDGELAS, S. 2008. Feasibility study for invasive predators' eradication in two lagoons IBA in New Caledonia. New Caledonia: Société Calédonienne d'Ornithologie/BirdLife International.
- BAUDAT-FRANCESCHI, J., SPAGGIARI, J. & BARRÉ N. 2009. Breeding birds of conservation interest. In: McKenna, S., Baillon, N. & Spaggiari, J. (Eds). A rapid marine biodiversity assessment of the coral reefs of the northwest lagoon, between Koumac and Yandé, Province Nord, New Caledonia. Rapid Assessment Program Bulletin of Biological Assessment no. 53. Arlington, VA: Center for Applied Biodiversity Science, Conservation International. pp. 64–69.
- BEALE, C.M. & MONAGHAN, P. 2004. Human disturbance: people as predation-free predators? *Journal of Applied Ecology* 41: 335–343.
- BELL, M. 1998. Seabird island restoration: New Caledonia. Eradication of rats, October 1998. Nouméa, New Caledonia: Wildlife Management International Ltd., Direction des Ressources Naturelles.
- BIRDLIFE INTERNATIONAL. 2011. Species factsheet: *Sterna nereis*. <http://www.birdlife.org> (30 January 2011).
- BOURNE, W.R.P., DAVID, A.C.F. & McALLAN, I.A.W. 2005. The birds of the Southern Coral Sea including observations by H.M.S. Herald in 1858–60. *Atoll Research Bulletin* 541: 237–263.

- CARNEY, K.M. & SYDEMAN, W.J. 1999. A review of human disturbance effects on nesting colonial waterbirds. *Colonial Waterbirds* 22: 68–79.
- CARTER, M. & MUSTOE, S. 2007. Another form of Fairy Tern *Sterna nereis* breeding in Australia Territory. *Australia Field Ornithology* 24: 167–179.
- CAUT, S., ANGULO, E. & COURCHAMP, F. 2008. Dietary shift of an invasive predator: rats, seabirds and sea turtles. *Journal of Applied Ecology* 45: 428–437.
- CONDAMIN, M. 1977. Mission aux Chesterfields du 29 Septembre au 7 Octobre 1977. *Nature Calédonienne* 16: 21–25.
- COX, J.B. & CLOSE, D.H. 1977. Interbreeding of Little Tern and Fairy Tern. *Emu* 77: 28–32.
- DE NAUROIS, R. & RANCUREL, P. 1978. Observations nouvelles sur les Laridae reproducteurs en Nouvelle-Calédonie. *Comptes Rendus de l'Académie des Sciences de Paris (Série D)* 287: 627–629.
- FERREIRA, S.M., HANSEN, K.M., PARRISH, G.R., PIERCE, R.J., PULHAM, G.A. & TAYLOR, S. 2005. Conservation of the endangered New Zealand Fairy Tern. *Biological Conservation* 125: 345–354.
- HANSEN, K. 2004. New Zealand Fairy Tern (*Sterna nereis davisae*) recovery plan, 2005–15. Threatened Species Recovery Plan 57. Wellington, NZ: Science & Technical Publishing, Department of Conservation, New Zealand Government.
- HIGGINS, P.J. & DAVIS, S.J.J.F. 1996. Fairy Tern. In Handbook of Australia, New Zealand and Antarctic birds. Vol 3. Snipes to Pigeons. Australia: Oxford University Press.
- HILL, R., BAMFORD, M., ROUNSEVELL, D. & VINCENT, J. 1988. Little Terns and Fairy Terns in Australia. Victoria, Australia: Royal Australasian Ornithologists Union.
- HITCHCOK, W.B. 1959. A review of the “Least” Tern in Australian waters. *South Australian Ornithologists* 22: 87–106.
- IMBER, M.J., WEST, J.A. & COOPER, W.J. 2003. Cook’s petrel (*Pterodroma cookii*): historic distribution, breeding biology and effects of predators. *Notornis* 50: 221–230.
- IUCN 2010. *Sterna nereis*. In: IUCN Red List of Threatened Species. Version 2010.4. www.iucnredlist.org (30 January 2011).
- KUSSER, J. & SUPRIN, B. 1990. Rapport de mission aux Chesterfield (11 décembre 89 au 22 décembre 89). Report Direction du Développement de l’Economie Rurale no. 3390–72.
- LAAKSONEN, T., AHOLA, M., EEEVA, T., VAISANEN, R.A. & LEHIKONEN, E. 2006. Climate change, migratory connectivity and changes in laying date and clutch size of the pied flycatcher. *Oikos* 114: 277–290.
- LAYARD, E.L. & LAYARD, E.L.C. 1882. Notes on the avifauna of New Caledonia. A catalogue of the birds of the island known to the authors. With remarks by the Rev. Canon Tristram. *Ibis* 4 (6): 493–546.
- NAPIER, J.R. 1972. Fairy and Little Terns breeding on Tasmania’s East Coast. *The Australian Bird Watcher* 4 (15): 103–109.
- O’CONNELL, T.J. & BECK, R.A. 2003. Gull predation limits nesting success of terns and skimmers on the Virginia barrier islands. *Journal of Field Ornithology* 74: 66–73.
- OLSEN, P. & MARPLES, T.G. 1993. Geographic variation in egg size, clutch size and date of laying of Australian raptors (Falconiformes and Strigiformes). *Emu* 93: 167–179.
- PATON, D.C. & PALTRIDGE, A. 2001. Status of Fairy Terns in South Australia: final report. Wildlife Conservation Fund Research Grant Project 2507. Adelaide, Australia: University of Adelaide.
- PANDOLFI-BENOIT, M. & BRETIGNOLLE, V. 2002. Seabirds of the Southern Lagoon of New Caledonia, distribution, abundance and threats. *Waterbirds* 25: 202–213.
- PARRISH, R. & HONNOR, L. 1997. New Zealand fairy tern (*Taraiti*) *Sterna nereis davisae* recovery plan 1997–2002. Threatened Species Recovery Plan 23. New Zealand: Department of Conservation, New Zealand Government.
- PARRISH, R. & PULHAM, G. 1995. Observations on the breeding of the New Zealand Fairy Tern. *Tane* 35: 161–173.
- RANCUREL, P. 1973. Compte rendu de mission aux Iles Chesterfield du 21 au 28 juin 1973. Paris, France: Office de la Recherche Scientifique et Technique d’Outre-Mer.
- RANCUREL, P. 1976. Notes ornithologiques. Liste préliminaire des oiseaux de mer des îles et Îlots voisins de la Nouvelle Calédonie. *Cahiers ORSTOM Oceanographie* 14 (2): 163–168.
- REED, T.E., WARZYBOK, P., WILSON, A.J., BRADLEY, R.W., WANLESS, S. & SYDEMAN, W.J. 2009. Timing is everything: flexible phenology and shifting selection in a colonial seabird. *Journal of Animal Ecology* 78: 376–387.
- ROBINET, O., SIRGOUANT, S. & BRETIGNOLLE, V. 1997. Marine birds of d’Entrecasteaux reefs (New Caledonia, Southwestern Pacific): diversity, abundance, trends and threats. *Colonial Waterbirds* 20: 282–290.
- ROSE, A.B. 2001. Predators of nesting Little Terns *Sterna albifrons* at Forster, New South Wales. *Australian Bird Watcher* 19: 79–87.
- ROSS, G.A., EGAN, K., PRIDDEL, D. 1999. Hybridization between Little Tern *Sterna albifrons* and Fairy Tern *Sterna nereis* in Botany Bay, New South Wales. *Corella* 23: 33–36.
- SECOMB, D. 1994. Silver Gull robbing Little Terns’ egg. *Australian Birds* 28: 56.
- SPAGGIARI, J., BARRÉ, N., BAUDAT-FRANCESCHI, J. & BORSA, P. 2007a. New Caledonian seabirds. In Payri, C. & Richer de Forges, B. (Eds). Compendium of marine species from New Caledonia. Documents Scientifiques et Techniques II, 7. Noumea, New Caledonia: L’Institut de recherche pour le développement. pp. 371–380.
- SPAGGIARI, J., CHARTENDRAULT, V. & BARRÉ, N. 2007b. Zones importantes pour la conservation des oiseaux de Nouvelle-Calédonie. Nouméa, New Caledonia: Société Calédonienne d’Ornithologie and BirdLife International.
- STAPP, P. 2002. Stable isotopes reveal evidence of predation by ship rats on seabirds on the Shiant Islands, Scotland. *Journal of Applied Ecology* 39 (5): 831–840.
- TARBURTON, M.K. 2001. Observations on the status of the land birds, wading birds and seabirds of Samoa. *Emu* 101 (4): 349–360.
- TAYLOR, G., HANSEN, K. & FERREIRA, S. 2004. Technical review of the New Zealand Fairy Tern recovery programme. New Zealand: Department of Conservation, New Zealand Government.
- WANLESS, S., HARRIS, M.P., LEWIS, S., FREDERIKSEN, M. & MURRAY, S. 2008. Later breeding in northern gannets in the eastern Atlantic. *Marine Ecology – Progress Series* 370: 263–269.
- WATLING, D. 2001. A guide to the birds of Fiji and western Polynesia. Suva, Fiji: Dick Watling Environmental Consultant.