Breeding Avifauna of the Chesterfield Islands, Coral Sea: Current Population Sizes, Trends, and Threats[1]

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Abstract: This paper reports on post-1991 census data and on the breeding phenology of seabirds of the Chesterfield-Bampton and Bellona groups of coral islets in the Coral Sea. In total, 13 resident bird species were observed [Wedge-tailed Shearwater (*Puffinus pacificus*), Masked Booby (*S. dactylatra*), Brown Booby (*Sula leucogaster*), Red-footed Booby (*S. sula*), Lesser Frigatebird (*Fregata ariel*), Great Frigatebird (*F. minor*), Black Noddy (*Anous minutus*), Brown Noddy (*A. stolidus*), Crested Tern (*Sterna bergii*), Sooty Tern (*S. fuscata*), Fairy Tern (*S. nereis*), Black-naped Tern (*S. sumatrana*), and Buff-banded Rail (*Gallirallus philippensis*)]. Segregation for nesting habitat was similar to that previously observed on other coral-reef islets of the Coral Sea. Breeding periods were either in the winter (Masked and Red-footed Boobies, Frigatebirds, Fairy Tern) or in the summer (Wedge-tailed Shearwater, Black and Brown Noddies, Crested and Black-naped Terns) or year-round (Brown Booby). Sooty Terns bred twice a year (summer and spring), but this was not consistent across years. Estimates of breeding population sizes for the whole Chesterfield-Bampton and Bellona groups are proposed for Wedge-tailed Shearwater (90,000 to 106,000 breeding pairs), Masked Booby (280–500 pairs), Brown Booby (3,800–5,800 pairs), Red-footed Booby (7,200–7,300 pairs), Lesser Frigatebird (1,600 pairs), Great Frigatebird (350–480 pairs), Black Noddy (29,000–45,000 pairs), Brown Noddy (15,000–23,000 pairs), Crested Tern (80–100 pairs), Sooty Tern (11,000–46,000 pairs), and Black-naped Tern (70–90 pairs). Interannual fluctuation in breeding population size was apparent in Wedge-tailed Shearwater. Over the last 30 yr, an increase in Brown Booby abundance was noted, whereas declines are suspected for the Fairy Tern and Buff-banded Rail. Among the threats to nesting seabirds are stress and other disturbances caused by human frequentation, including poaching of seabird chicks and introduced mice.

In the central Coral Sea, approximately 19° 05′ S to 21° 50′ S and 158° 15′ E to 159° 35′ E (Figure 1), lies an archipelago of uninhabited coral sand cays and vegetated islets amidst a complex of reefs that delineates the edges of the Chesterfield and Bellona geological plateaus (Missègue and Collot 1987). Because of their isolation from human settlements, their proximity to the presumably resource-rich waters of the southern Coral Sea, and the occurrence of various types of vegetation that provide nesting habitats, those islands are home to large seabird colonies (Bourne et al. 2005). The Chesterfield Islands were occupied by nineteenth-century

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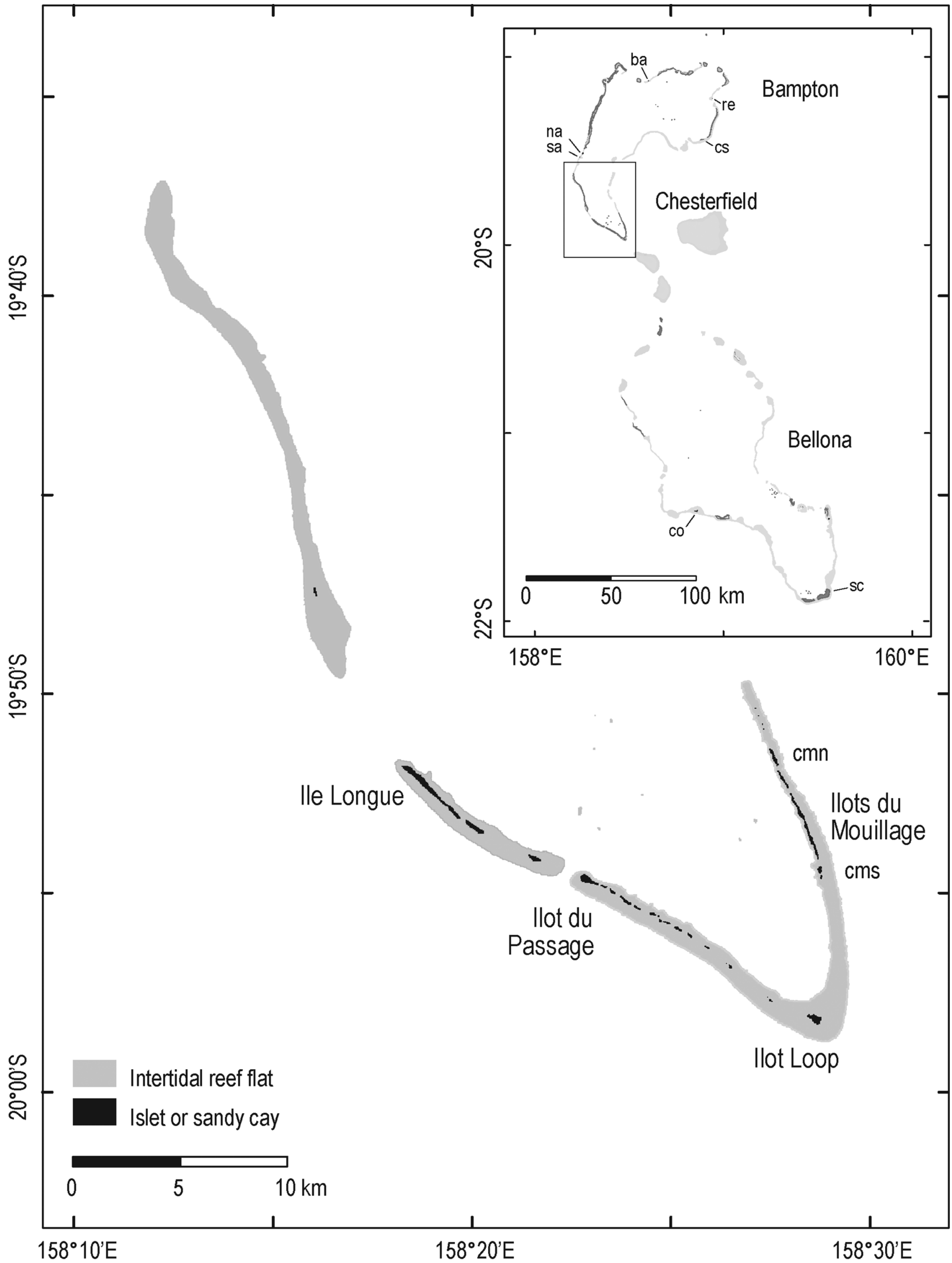

FIGURE 1. Map of the study area (Chesterfield islands and lagoon). Inset: Map of the Bampton-Chesterfield-Bellona group of reefs. ba, Bampton islet; re, Renard; cs, Caye Skeleton; na, North Avon; sa, South Avon; co, Caye de l'Observatoire; sc, Sandy Cay; cmn, vegetated cay north of Mouillage islets; cms, vegetated cay south of Mouillage islets.

whalers, as testified by sperm whale carcasses and remains of a large melter that still littered Ile Longue in recent years (Rancurel 1973, Pandolfi-Benoit 1997), and exploited from 1877 to 1888 by guano diggers (Rancurel 1973, Bourne et al. 2005), who eventually left them bare of their tall vegetation with the seabird colonies on them presumably decimated (Anonymous 1916, Bourne et al. 2005).

Since the surveys by the ship *Herald* in 1859 (Bourne et al. 2005), researchers briefly visited the Chesterfield Islands in 1957 (Cohic 1959) and on a few additional occasions (Rancurel 1973, 1974 *in* Bourne et al. 2005, Condamin 1977) after the installation of an automatic meteorological station on Ilot Loop in 1968 (Anonymous 1968) and reported on seabird abundance and breeding phenology. More recent data, from a field trip by naturalists T. A. Walker and F. Savage in 1990, were synthesized by Bourne et al. (2005), yielding tentative population size estimates for 10 seabird species for the southern part of the Chesterfield-Bampton group.

Here we present a review of the census data on the avifauna of the Chesterfield Islands and islets and sandy cays of the adjacent Bampton and Bellona reef systems, gathered since 1991. The objectives of this study are (1) to present, for the first time, the breeding number estimates for all seabird species from the whole Chesterfield-Bampton and Bellona groups; (2) to infer the trends in population size by comparing current (i.e., post-1991) estimates with those reported earlier (1973–1990); (3) to infer the egg-laying periods from the breeding data; and (4) to assess the potential threats to the breeding avifauna.

MATERIALS AND METHODS

Study Area

Figure 1 presents a simplified map of reef geomorphological features of the Chesterfield group, highlighting intertidal reef flats and islands (both with and without vegetation). Figure 1 was derived from a Landsat image acquired on 6 September 1999 and available through the Millennium Global Coral Reef Mapping image archive (Andréfouët et al. 2006). The spatial resolution is 30 m. Vegetated surfaces on the islets of the Chesterfield Islands were obtained by thresholding the near-infrared band (Landsat band 5) to separate the vegetated and nonvegetated land pixels from submerged areas and counting each of the 900-m^2 pixels in both classes of land. No tide correction was applied to the imagery and surface estimates. The shallow reef flats were totally submerged at the time of the acquisition, thus tide was close to its highest. The map presented in the inset (Figure 1) was obtained by also using the data from two other Landsat images, treated in a similar way. Total reef and lagoon area of the Bampton-Chesterfield-Bellona group has been reported previously (Andréfouët et al. 2007). Table 1 presents the total and vegetated areas of the islets and summarizes the number and dates of visits made by us to each islet. The altitude of the islets, at ground level, is ca. 2–5 m.

Ilot Loop and Ile Longue are the two islets of the Chesterfield Islands that have been most visited. Together with Ilot du Passage, which was visited once in December 1990 (Bourne et al. 2005) but unfortunately was not visited by us, they make up the larger islets of the Chesterfield Islands sensu stricto (Table 1). All three possess trees and shrubs (including *Heliotropium foertherianum*, *Scaevola taccada*, *Abutilon indicum*), thus allowing the nesting of Red-footed Booby (*Sula sula*), Lesser and Great Frigatebirds (*Fregata ariel* and *F. minor*), and Black Noddy (*Anous minutus*). A few coconut trees have also been planted amidst the lower vegetation of the interior of Ile Longue. Bampton is a forested islet with tall *Pisonia grandis* trees, and at the time of our visit Renard islet was covered mainly with bush and dead *Pisonia grandis* trees. All the other islets are low sandy cays covered with some bushes and eventually low vegetation (*Boerhavia repens* and grasses) or with no vegetation at all.

Counting Methods

Counting methods varied to some extent between observers and also varied with species.

TABLE 1

Study Sites Including All Vegetated Islets and Cays and Review of Recent Visit and Fieldwork (since 1991)

Islet	Coordinates		Area		Visits	
	Latitude	Longitude	Total	Vegetated	Date	Source
Bampton group						
Bampton	19° 07′ S	158° 36′ E	3.8 ha	2.6 ha	29 June 1996; 9 Feb. 2001	M.P. (unpubl. data); V.B. and M.P. (unpubl. data)
Renard	19° 13′ S	158° 56′ E	8.1 ha	6.4 ha	28 June 1996; 9 Feb. 2001	M.P. (unpubl. data); V.B. and M.P. (unpubl. data)
Caye Skeleton	19° 26′ S	158° 53′ E	0.3 ha	—	1 July 1996	M.P. (unpubl. data)
North Avon	19° 31′ S	158° 15′ E	3.7 ha	2.2 ha	16 Nov. 1995	M.P. (unpubl. data)
South Avon	19° 32′ S	158° 14′ E	3.1 ha	0.5 ha	16 Nov. 1995	M.P. (unpubl. data)
Chesterfield Islands						
Ile Longue	19° 52′ S	158° 19′ E	40.2 ha	18.2 ha	14–15 Nov. 1995; 24 Jan. 1996; 14 May 1997; 19–20 June 2007	Pandolfi-Benoit (1997); Borsa and Boiteux (2007); M.P. (unpubl. data)
Ilots du Mouillage	19° 52–54′ E	158° 27–29′ E	23.4 ha	4.9 ha	Jan 1991; 13 May 1997; 28–30 Jan. 2009	Pandolfi-Benoit (1997); Borsa (2009); S. Sirgouant (unpubl. data)
Passage	19° 55′ S	158° 23′ E	13.0 ha	4.9 ha	—	—
Loop	19° 58′ S	158° 29′ E	4.6 ha	3.8 ha	Jan. 1991; 13–16 Feb. 1993; 7 Nov. 1993; 8 Mar. 1994; 13 May 1997; 8 Feb. 2001; 12–14 Dec. 2005; 22–24 Oct. 2008; 28–30 Jan. 2009	Pandolfi-Benoit (1993); Pandolfi-Benoit (1997); Borsa (2006); Borsa (2008); Borsa (2009); M.P. (unpubl. data); V.B. and M.P. (unpubl. data); S. Sirgouant (unpubl. data)
Bellona group						
Caye de l'Observatoire	21° 24′ S	158° 28′ E	14.1 ha	8.7 ha	Jan. 1996; 7 Feb. 2001	M.P. (unpubl. data); V.B. and M.P. (unpubl. data)
Sandy Cay	21° 48′ S	159° 33′ E	1.1 ha	—	7 Feb. 2001	V.B. and M.P. (unpubl. data)

Note: Ilots du Mouillage consists of a string of four vegetated sandy cays connected by sandbanks and two isolated vegetated cays, one to the north and one the south of the four islets (Figure 1). Duration of visit at an islet ranged between a few hours and 2.5 days.

For Wedge-Tailed Shearwater (*Puffinus pacificus*) and Sooty Tern (*Sterna fuscata*) and in some cases Brown (*Sula leucogaster*) and Red-footed Boobies, frigatebirds, and noddies, we used the transect method (see Robinet et al. 1997). Transects were 4–6 m wide and sampled 0.9% to 16.0% of the surface of an islet. They were chosen to cross the entire width of islets to sample birds nesting in each type of habitat with as little bias as possible. Transect length was calculated using topographic wire or a GPS receiver, or a posteriori by superposing the transect line to the Landsat image. Burrow entrances were counted for Wedge-tailed Shearwater, fledglings or nests for Sooty Tern and in some cases boobies and frigatebirds, and nests otherwise and for all the other breeding seabird species. When possible, the number of individuals, whether nesting or roosting, was also counted. For instance, Masked Boobies (*S. dactylatra*) on all islets and Red-footed Boobies on Loop were counted exhaustively (in February 1993, May 1996, December 2005, June 2007), preferably after sunset when their abundance was highest. For species that were not nesting at the time of the visits, individuals were counted either in flight before sunset (Sooty Tern above Loop on December 2005) or else landed. The rather secretive Buff-banded Rail (*Gallirallus philippensis*) was noted opportunistically.

On many occasions, the numbers of Lesser Frigatebirds and Great Frigatebirds were mixed, especially when only half-grown chicks were present on the breeding colonies. On some occasions, however, we were able to determine the ratio of population size of the two species from the relative abundances of adults and we back converted total numbers of nests accordingly. Counts of nests included unattended eggs or chicks in nests that appeared to be active and adults that appeared to be incubating or brooding. Birds were not intentionally disturbed to ascertain nest content. Estimates of breeding population size can be proposed by relying on those counts that were made at the peak of the breeding season, in those species for which a peak can be identified.

Temporal Change

To examine temporal changes in the avifauna of the Chesterfield Islands, we compiled information from previous ornithological surveys, from 1973 to 1990 (references in Table 2 and Table 3) and compared the post-1991 data to it. The 1973–1990 information was also used in addition to the post-1991 data to tentatively determine the breeding seasons for each species.

RESULTS

Nesting Habitats

Wedge-tailed Shearwaters nested on almost all islets, under the low vegetation (mainly grasses and *Boerhavia repens* herb: Ile Longue, Loop, Mouillage), below bushes (Bampton), or below trees (Renard). No burrows were present on sandy cays, however. Masked Boobies had their rudimentary nests at the top of the beach of vegetated islets, either on coral rubble and sand out of reach of the higher tides or in the grass on the vegetated crest atop the beach. Brown Boobies laid their eggs on rudimentary nests on the ground in the open part of islets, and Red-footed Boobies built their large nests exclusively in the canopy of *Pisonia grandis*, *Heliotropium foertherianum*, and *Scaevola taccada* trees. Frigatebirds built their nests on *Abutilon indicum* shrubs or in the canopy of trees. Black Noddy nests were made of vegetable matter including algal thalli, grass leaves, and twigs stuck together by feces and were built exclusively under the canopy on the branches of trees at the periphery of islets. Brown Noddy nests were generally rudimentary and installed on the ground in the low vegetated parts of islets, either on the higher part of the beach, or on the flat of the islet, or at the base of *H. foertherianum* trees or in their canopy, close to Black Noddy nests, or were constructed low in shrubs. A large proportion of the trees used by Red-footed Boobies and noddies for nesting on Loop and Ilots du Mouillage were dead. Sooty Terns and Crested Terns (*Sterna bergii*) nested on the low-vegetated flat of some islets or on sand.

TABLE 2

Population Size Estimates for the Seabirds and Buff-banded Rail Encountered during Visits at Ilot Loop, Chesterfield Islands

Species / Visit (Reference)	June 1973 (R73)	Apr. 1974 (R74)	Oct. 1977 (C77)	Dec. 1990 (w05)	Jan. 1991 (s91)	Feb. 1993 (P93)	Nov. 1993 (p93)	Mar. 1994 (p94)	May 1997 (P97)	Feb. 2001 (b01)	Dec. 2005 (B06)	Oct. 2008 (B08)	Jan. 2009 (B09)
Puffinus pacificus	—	+	—	1 i	—	7,686 b	8,004 b	8,600 b	11,068 b	9,660 b	6,039 b	6,144 b	5,836 b
Sula dactylatra	1–2 p	+	55 i (28 p)	100 i	107 i	88 i (23 p)	103 i (13 p)	84 i (11 p)	~40 i	70 i (3 p)	46 i (9 p)	62 i (26 p)	37 i (17 p)
Sula leucogaster	+	+	22 i (1 p)	10 i	—	59 i (>27 p)	70 i	90 i (4 p)	12 p	150 i (100 p)	34 p	85 p	54 p
Sula sula	+	+	300 p	50 i	910 i	1,435 i	794 i (~150 p)	493 i	86 p	<100 p	896 i (28 p)	165 p	80 p
Phalacrocorax sulcirostris	—	—	+	—	—	—	—	—	—	—	—	—	—
Fregata ariel	—	+	+	8 i	—	—	—	1 i	—	2 i	—	—	2 i
Fregata minor	+	+	+	—	—	—	3 i	2 i	—	—	2 i	1 i	3 i
Anous minutus	++	+	+	—	—	1,900 p	1,282 p	336 p	50 i (>4 p)	660 p	390 p	~500 i (>5 p)	551 p
Anous stolidus	++	+	545 i	—	—	1,695 p	+	>2,000 i (4 p)	~100 p	225 p	~80 i	~70 i (18 p)	443 p
Gygis alba	—	+	—	—	—	—	—	—	—	—	—	—	—
Sterna bergii	—	5–6 p	1 p	—	—	1 i	—	14 i	12 p	5 i	—	1 i	44 i (20 p)
Sterna fuscata	++ (p)	+ (p)	2,000–3,000 i	300 i	9,000 p	16,158 p	10,000 i (1,500 p)	500 i (~100 p)	++	2,500–3,000 p	3,000–5,000 i	1,060–1,300 p	540 i
Sterna nereis	10 i	—	—	—	—	—	—	7 i	—	—	—	—	—
Sterna sumatrana	—	—	—	15 i	—	17 i	50 i	2 i	—	6 i	—	10 i	33 i
Gallirallus philippensis	++	++	1 i	—	—	3 i	—	1 i	1 i	>3p	1 i	1 i	—

Note: i, individuals; b, burrows; p, breeding pairs (deduced from either adults incubating, unattended chicks, or fledglings); +, reported as present; ++, reported as abundant; —, species either reported as absent or no data.

Abbreviations for references: R73, Rancurel (1973); R74, Rancurel (1974 *in* Bourne et al. 2005); C77, Condamin (1977); w05, T. A. Walker and F. Savage *in* Bourne et al. (2005); s91, unpubl. obs. by S. Sirgouant, 1991; P93, Pandolfi-Benoit (1993); p93, unpubl. obs. by M.P., 1993; p94, unpubl. obs. by M.P., 1994; P97, Pandolfi-Benoit (1997); b01, unpubl. obs. by V.B. and M.P., 2001; B06, Borsa (2006); B08, Borsa (2008).

TABLE 3

Population Size Estimates for the Seabirds and Buff-banded Rail Encountered during Visits at Ile Longue (Long), Ilots du Mouillage and Adjacent Cays (Mouillage), and Passage Islet (Passage)

Species	Long							Mouillage							Passage
Visit	June 1973	Oct. 1977	Dec. 1990	Nov. 1995	Jan. 1996	May 1997	June 2007	June 1973	Oct. 1977	Dec. 1990	Jan. 1991	May 1997	Jan. 2009		Dec. 1990
Reference	(R73)	(C77)	(w05)	(p95)	(p96)	(P97)	(B07)	(R73)	(C77)	(w05)	(s91)	(P97)[a]	(B09)		(w05)
Puffinus pacificus	—	—	+	+	25,600 b	—	7,407 b	—	—	++	—	4 b	1,235 b		+
Phaethon rubricauda	1 i	—	—	—	—	—	—	—	—	—	—	—	—		—
Sula dactylatra	—	+	300 i	+	+	14 i (1 p)	73 i	+	+	444 i	—	+	44 p		39 i
Sula leucogaster	+	++	650 i	∼1,000 i (∼1,000 p)	2,900 i (1,500 p)	2 p	1,962 p	+	+	161 i	—	∼100 p	576 p		458 i
Sula sula	+	+	199 i	>100 i	>100 i	4 p	1,810 p	+	+	380 i	—	∼100 p	1,222 p		274 i
Phalacrocorax sulcirostris	—	—	—	—	—	—	—	—	10 i	—	—	—	—		—
Fregata ariel	—	—	—		4 i	—	—	+	+	—	—	∼50 p	282 i (40 p)		200 i
Fregata minor	++	>60 p	—	>100 i	60 i	>100 p	194 p	+	+	152 i	—	∼50 p	94 i (14 p)		12 i
Anous minutus	+	—	300 i	1,000–2,000 i	1,000–2,000 i (13 p)	>100 p	6,012 p	+	—	>1,000 p	—	+ (p)	12,201 p		250 i
Anous stolidus	+		200 i	1,000–2,000 i	150 i (31 p)	++	7,082 p	+	++	2,000 i	—	>10 p	251 p		750 i
Sterna bergii	—	—	—	—	32 i	—	—	—	—	—	—	—	16 i		—
Sterna fuscata	—	+	1 i	10 i	5 i	—	—	—	+	63 i	+?	—	1 p		16 i
Sterna nereis	+	+	—	—	—	—	—	+	12 i	—	5 i	—	—		—
Sterna sumatrana	—	—	2 i	—	—	—	—	+	2 i	—	58 p	—	29 i		23 i
Gallirallus philippensis	++	++	—	—	4 i	1 i	+	++	1 i	—	—	1 i	9 i		—

Note: Abbreviations for references: B07, Borsa and Boiteux (2007); p95, unpubl. obs. by M.P., 1995; p96, unpubl. obs. by M.P., 1996. Other abbreviations as in Table 2.

[a] Data relative to one of the three islets that made Ilots du Mouillage in 1997.

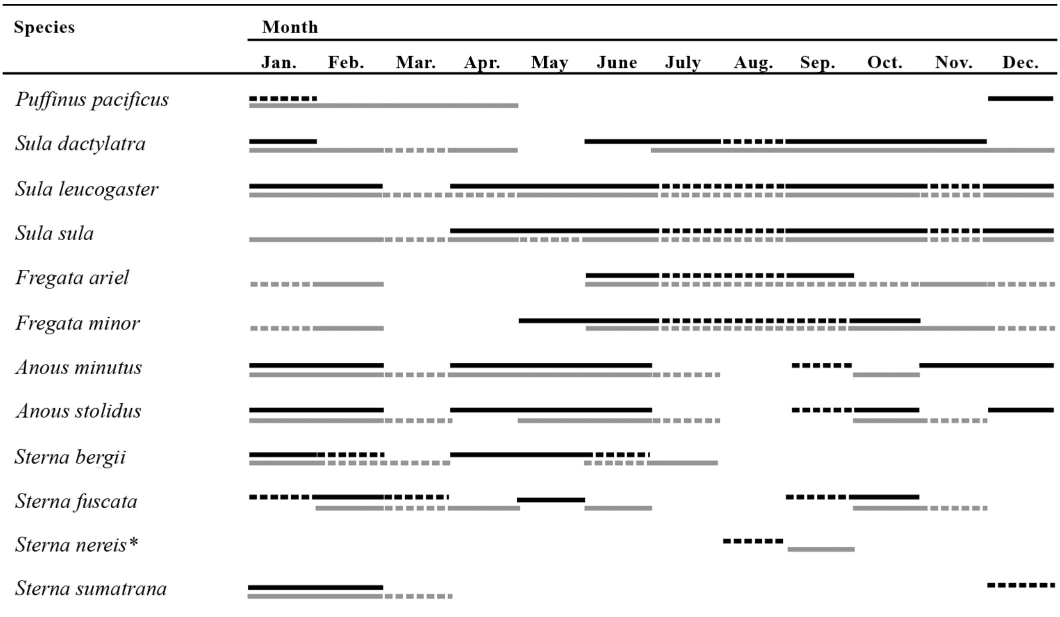

Figure 2. Breeding phenology of seabirds on islets of the Chesterfield-Bampton and Bellona groups, compiled from all reports and unpublished data gathered since 1957 (Cohic 1959, Rancurel 1973, 1974 *in* Bourne et al. 2005, Condamin 1977; other sources detailed in Table 1). Extent of each stage of the breeding cycle was extrapolated from incubation and fledging durations in other locations (Marchant and Higgins 1990, Higgins and Davies 1996). *Breeding data for Fairy Tern from Rancurel (1976). Black, eggs; gray, chicks; solid, observed; dashed, extrapolated.

Black-naped Terns (*S. sumatrana*) nested on the sand and coral rubble of the beach.

Breeding Periods

The breeding phenology of seabirds on the Chesterfield-Bampton and Bellona islets was compiled from all reports and unpublished data gathered since 1957 (Cohic 1959, Rancurel 1973, 1974 *in* Bourne et al. 2005, Condamin 1977; other sources in Table 1). This allowed us to tentatively establish the egg-laying periods for each species (Figure 2). More details are given in the following account by species.

Wedge-tailed Shearwaters were present during the summer months only, from October to April, with egg incubation beginning in December and finished by February.

Masked Boobies were observed incubating eggs from June to January. The peak of egg laying appeared to be between June and October because the proportions of nests with eggs in January, February, June, September, October, November, and December were, respectively, 3.9% ($n = 51$), 0% ($n = 35$), 41.7% ($n = 24$), 57.1% ($n = 28$), 46.2% ($n = 26$), 18.4% ($n = 49$), and 8.0% ($n = 25$).

Brown Booby eggs were found from April to February. Chicks at various stages of development were found year-round. Transect data from Ile Longue in January 1996 and from Bampton, Renard, Loop, and Caye de l'Observatoire in early February 2001 provided quantitative estimates. The proportions of nests with eggs, small chicks, and unattended chicks were, respectively, 19.1%, 70.2%, and 10.6% ($n = 47$). On Caye de l'Observatoire, large unattended chicks were found at the end of January 1996, but only flying fledglings were found in early February 2001. This suggests that a peak of laying may actually occur between August and October.

Red-footed Boobies laid eggs from April

to December, and chicks were found year-round. Transect data at various sites and dates showed 100% eggs in June ($n = 21$); 33% eggs in November ($n = 150$); no eggs and large unattended chicks or nearly fledged birds in December ($n = 28$); no eggs, 53% large unattended chicks and 48% nearly fledged birds in January ($n = 120$); and no eggs, 14.5% large unattended chicks, and 85.6% nearly fledged birds in February ($n = 94$). Therefore, a peak of egg laying occurs in winter months (i.e., June–October).

Frigatebird eggs of both species were found from May–June to September–October, hatchlings from June to November, brooded chicks from June to November, unattended chicks from August to November, and fledglings until February. Transect data in February indicated that Lesser Frigatebirds were displaying and juveniles were fledging, and only large chicks and fledglings were found for Great Frigatebird. Frigatebirds therefore bred in the winter and appeared more synchronized than boobies, and there was indication that Great Frigatebirds breed slightly later than Lesser Frigatebirds.

Black Noddy eggs and chicks were found from November to June. A few attended chicks were also reported in mid-October, indicating that some egg laying took place in September. The proportion of birds incubating eggs throughout the summer was 0% ($n = 24$), 50.0% ($n = 100$), 93.7% ($n = 160$), 32.5% ($n = 40$), and 71.2% ($n = 66$) in, respectively, October, November, December, January, and February, indicating a peak in December, although the egg-laying period extended up to the colder months of April to June.

Brown Noddy eggs were found in October and from December to June, in a pattern overly similar to that of Black Noddy. Using counts made during transects in January on Ile Longue, 68% of nests were with eggs ($n = 31$ nests). In February on Caye de l'Observatoire, 278 eggs, 33 small chicks, and 220 large chicks were found ($n = 531$), suggesting two waves of breeding. In the same month but in different years, on Loop, 88% of nests were with eggs ($n = 16$), and on Bampton and Renard, 96% of nests were with eggs ($n = 282$). In May on Loop, only 39% of nests were with eggs; the others were with chicks ($n = 109$). It therefore appears that Brown Noddy is able to breed at any time of the year but apparently shows two waves of laying, one at the beginning of winter (April–June), the other in the summer (October–February).

Crested Tern eggs were found in April and May, chicks in May and June, and a few non-flying fledglings in January, suggesting that breeding occurs mainly at the end of summer. However, a few eggs were also found at the end of January in 2009, and more birds were apparently ready to lay eggs then.

Sooty Terns showed two, perhaps three, periods of egg laying: eggs were found in October, February, and May. In February 2001, breeding colonies included egg-laying birds (either starting to breed on Caye de l'Observatoire or building nests on Loop) as well as fledgling birds. Therefore, this was a second breeding attempt.

Fairy Tern (*Sterna nereis*): The only proof that this tern breeds in the Chesterfield Islands was the observation made of nearly fledged chicks in late September 1974 (Rancurel 1976), suggesting egg laying in August.

Black-naped Terns were observed in small numbers mostly in the summer; eggs and chicks were reported from January and February only.

Population Size Estimates

Wedge-tailed Shearwater burrow density was variable among islets (from 0.16 up to 0.51 per m^2) and also across visits (e.g., on Loop: 0.23 in February 2001 and May 1997 versus 0.16 per m^{-2} in February 1993 and December 2005). It should be noted that the area of low vegetation suitable for Wedge-Tailed Shearwater burrows at Loop had shrunk from 4.9 ha in February 1993 (Pandolfi-Benoit 1993) to 3.6 ha (determined from the 1999 Landsat image). Wedge-tailed Shearwater nested at high density on Renard (0.51 burrow per m^2) and Bampton (0.45 burrow per m^2, on two-thirds of the islet). They also bred on Ilots du Mouillage and Avon in small numbers (Tables 3, 4). On Bellona islets,

TABLE 4

Population Size Estimates for the Seabirds Encountered during Visits at Islets of the Bampton and Bellona Groups

	Bampton		Renard		N, S Avon		Skeleton	Observatoire		Sandy Cay
Species	June 1996	Jan. 2001	June 1996	Jan. 2001	Dec. 1990	Nov. 1995	July 1996	Jan. 1996	Jan. 2001	Jan. 2001
Puffinus pacificus	—	7,800 b	—	35,000 b	3 b	~50 b	>10 b	13,920 b	25,230 b	—
Sula dactylatra	6 p	36 p	515 i (21 p)	300 i (140 p)	22 i	10–25 p	2 i	12 p	64 p	70 i
Sula leucogaster	—	832 p	—	1,152 p	62 i	50–100 p	—	1 p	300 i	—
Sula sula	—	600 p	—	4,200 p	48 i	—	—	—	360 p	—
Fregata ariel	—	410 p	—	1,071 i (571 p)	17 i	100 i	—	—	~400 p	—
Fregata minor	—	—	—	429 i (229 p)	2 i	—	—	—	—	—
Anous minutus	—	3,400 p	10,000 i	20,000 p	200 p	—	—	—	2,400 p	—
Anous stolidus	1 p	450–500 p	—	200 p	510 i	>500 i	100–200 i (15 p)	—	13,000 p	>500 p
Sterna bergii	12 p[a]	2 p	—	—	—	—	10 p	—	4 p	50 p
Sterna fuscata	10,400 p	800–1,000 p	—	—	4,150 i	5,000–10,000 p	—	5,000–10,000 p	2,500 p	—
Sterna sumatrana	—	—	—	—	183 i	+	—	—	45 i (6 p)	—

Source: Unpubl. data by V.B. and M.P. except N, S Avon, December 1990, from T. A. Walker and F. Savage *in* Bourne et al. (2005).
Note: Abbreviations as in Table 1.
[a] On the sandy cay immediately west of Bampton.

Wedge-tailed Shearwaters bred on Caye de l'Observatoire only (0.29 burrow per m^2 in 2001 but 0.16 burrow per m^2 in January 1996). Population size estimates, derived from burrow densities, are provided in Tables 2–4. The difference in burrow abundance estimate between January 1996 (25,600) and June 2007 (7,049) on Ile Longue (Table 3) may be partly ascribed to differences in the density of low vegetation that, when conditions are favorable, can grow rapidly so as to hide burrow entrances, which is why only estimates from data acquired during the breeding season were kept in Table 5. It may also reflect actual trends in breeding population size, with interannual fluctuation nearly twofold on Loop and Caye de l'Observatoire (Table 5).

Masked Booby: The numbers of breeding pairs at different visits on Longue, Loop, and Ilots du Mouillage are given in Tables 2 and 3. Those at the Bampton and Bellona islets are given in Table 4. We conservatively estimate the total breeding population for this species at between 280 and 500 pairs (Table 5).

Brown Booby: On the central Chesterfield Islands, the main colony was on Ile Longue, with >1,900 nests in June 2007 and up to 2,900 pairs (1.6 nests per 100 m^2) in January 1996 (Table 3). Brown Boobies bred on both Avon islets (November 1995), but were more numerous on South Avon. On Caye de l'Observatoire, only one nest was found in January 1996, and there was no proof of breeding in January 2001, although 300 adults and flying fledglings were present. On Renard, nest density was 1.8 per 100 m^2 in January 2001; on Bampton, it was 3.2 per 100 m^2, yielding the estimated numbers of breeding pairs reported in Table 4. Brown Boobies apparently do not breed on Caye Skeleton, though adults were seen.

Red-footed Booby: Bred on Ile Longue, where the number of breeding pairs could be estimated at the presumed peak of the egg-laying season (~1,800 pairs in June 2007 [Table 3]), and on Loop and Ilots du Mouillage (Tables 2, 3). Nearly 5,000 breeding pairs were estimated on Bampton and Renard, and 360 pairs were found on Caye de l'Observatoire in January 2001 (Table 4).

Lesser Frigatebird: Bred on Bampton, Avon islets, and Ilots du Mouillage, where 50 nests were found in May 1997. Breeding Lesser Frigatebirds were absent from Loop and Ile Longue (Tables 2, 3). Eight hundred frigatebird nests were counted on Renard (January 2001: end of breeding season), together with a roost of an estimated 1,500 birds where Lesser Frigatebirds outnumbered Great Frigatebirds by a ratio of 2.5 to 1, suggesting that ca. 570 nests of Lesser Frigatebird may have been present. Approximately 400 nests were counted on Caye de l'Observatoire on the same date.

Great Frigatebird: Breeders of this species are less numerous than those of Lesser Frigatebird. The main breeding colonies were on Ile Longue and Renard (230 pairs, based on the ratio to Lesser Frigatebirds in the evening roost count, January 2001).

Black Noddy: Loop and Ile Longue held large populations of this species (Tables 2, 3), which also bred on Ilots du Mouillage. Respectively, 3,400, nearly 20,000, and 2,400 breeding pairs were estimated on Bampton, Renard, and Caye de l'Observatoire (January 2001).

Brown Noddies bred on all islets and cays (Tables 2–4). Overall, the total population size over the study area exceeded 15,000 breeding pairs (Table 5).

Crested Tern: Small breeding populations were observed on Bampton and on an adjacent sandy cay; also on Skeleton, Loop, Caye de l'Observatoire, and Sandy Cay. Overall population size may be less than 100 pairs (Table 5).

Sooty Terns bred on Bampton, North and South Avon, Loop, and Caye de l'Observatoire (Tables 2–4). It is unlikely that Sooty Terns breed on Renard because of the lack of suitable habitat (beach or low vegetation), and we did not observe them on Ile Longue, despite apparently favorable conditions for nesting.

Fairy Tern: Only a few adults were seen (Ilots du Mouillage, January 1991; Loop, March 1994). None was seen on other islets

TABLE 5

Summary of Current (Post-1991, except Where Indicated) Seabird Population Size Estimates (in Breeding Pairs, Rounded Estimates) on Islands of the Chesterfield-Bampton and Bellona Groups

	Island Group										
	Bampton Group				Chesterfield Islands				Bellona Group		
Species	Bampton	Renard	Skeleton	N, S Avon	Loop	Ile Longue	Mouillage	Passage[a]	Observatoire	Sandy Cay	Total
Puffinus pacificus	8,000	35,000	>10	50	6,000–11,000	26,000	1,200	+	14,000–25,000	—	90,000–106,000
Sula dactylatra	40	140–250	?	10–25	10–30	10–35	44	12	12–64	—	280–500
Sula leucogaster	830	1,150	—	50–100	10–100	1,000–2,900	600	150	1	—	3,800–5,800
Sula sula	600	4,200	—	—	80–150	1,800	1,200	90	360	—	7,200–7,300
Fregata ariel	410	570	—	50–100	—	—	40–50	75	400	—	1,550–1,600
Fregata minor	—	230	—	—	—	100–200	14–50	4	—	—	350–480
Anous minutus	3,400	5,000–20,000	—	200[a]	340–1,000	6,000	12,000	100	2,400	—	29,000–45,000
Anous stolidus	450–500	200	15	>170	40–1,700	30–7,100	250	250	13,000	>500	15,000–23,000
Sterna bergii	2–12	—	10	—	12–20	—	—	—	4	50	80–100
Sterna fuscata	800–10,400	—	—	5,000–10,000	100–16,000	—	+	?	5,000–10,000	—	11,000–46,000
Sterna nereis	—	—	—	—	—	—	?	—	—	—	?
Sterna sumatrana	—	—	—	+	3–17	—	58	?	6–15	—	70–90

Note: +, some nesting reported; ?, insufficient data.

[a] From T. A. Walker and F. Savage *in* Bourne et al. (2005).

despite substantial sighting effort. The current breeding status of Fairy Tern in the study area is uncertain.

Black-naped Tern: Only adults were seen on Bampton, Avon, Loop, and Skeleton (Tables 2–4). The only evidence of breeding comes from Ilots du Mouillage in January 1991 (58 nests) and Caye de l'Observatoire in January 2001 (at least six pairs, two with eggs, four fledglings, and 45 adults), but Bampton, Avon, Skeleton, and Loop may also occasionally harbor small colonies. The current population size over the whole study area was apparently less than 100 pairs (Table 5).

DISCUSSION

Species Diversity

Fourteen seabird species, including 12 confirmed breeders, have been observed in the Chesterfield Islands since Cohic's treatment (1959). This is only a fraction of the 28 seabird species that breed in the New Caledonia Archipelago (Spaggiari et al. 2007). In comparison, 16 have been reported for the southern lagoon of New Caledonia (Pandolfi-Benoit and Bretagnolle 2002, Spaggiari et al. 2007) and 12–14 from the islets of d'Entrecasteaux Reefs (Robinet et al. 1997). No Procellariidae species other than Wedge-tailed Shearwater, nor Bridled Tern (*Sterna anaetheta*), Roseate Tern (*S. dougallii*), or Silver Gull (*Larus novaehollandiae*) were observed at the Chesterfield-Bampton-Bellona islands, although those species are present in apparently similar habitats elsewhere in the Coral Sea (Rancurel 1976, Johnstone 1982, Bretagnolle and Pandolfi-Benoit 1997, Blaber et al. 1998, Pandolfi-Benoit and Bretagnolle 2002, Spaggiari et al. 2007). There was no conclusive evidence of breeding in Red-tailed Tropicbird (*Phaethon rubricauda*), which nests on Surprise (Robinet et al. 1997) and on other islets of the Coral Sea (King 1993) and apparently bred in the Chesterfield Islands in the nineteenth century (Thiercelin 1866). The Herald Petrel (*Pterodroma heraldica*) was also presumably breeding (three birds were collected in 1859 [see Bourne et al. 2005]). The lower species richness of those islands may be related to their isolation in the middle of the Coral Sea, their relatively small surface, which entails competition for nesting sites, and their history of intense human disturbance. It is also notable that the Fairy Tern has not been reported breeding in the Chesterfield Islands since 1974 (Rancurel 1976, de Naurois and Rancurel 1978).

Breeding Periods

A proportion of the seabird species in the Chesterfield-Bampton-Bellona area (namely, Wedge-tailed Shearwater, Black and Brown Noddies, and Black-naped Terns) breed in the summer as do most seabird species south of the Coral Sea (Robinet et al. 1997). Other species (Masked Booby, Red-footed Booby, both Frigatebirds, and Fairy Tern) breed in the winter. Yet another species (Brown Booby) lays eggs year-round, and another (Sooty Tern) reproduced in an apparently erratic fashion. Whether those seasonal preferences or lack of preference result from adjustment to some seasonality in the availability of prey (or lack of it), or are mainly dictated by thermoregulatory constraints, or are genetically determined, remains to be investigated. The Sooty Tern breeds seasonally in the southern Mozambique channel and the Seychelles, every nine and a half months on Ascension Island, twice a year on the Pacific Christmas Island, and at 6-month intervals or nonseasonally elsewhere (Ashmole 1963, Schreiber and Ashmole 1970, Jaquemet et al. 2007). This apparent plasticity in breeding frequency may be a response to temporal and/or spatial fluctuation in food abundance, under the constraint of breeding synchronization for the whole colony. A possible advantage of nonseasonality may be the avoidance of parasites (Bourne et al. 2005) and predators.

Population Sizes

Population size estimates at a given site generally varied by several orders of magnitude across visits (Tables 2, 3). Reasons for this may be the heterogeneity in the methods used by various researchers to estimate population sizes and the errors inherent in estimation. Another reason is seasonality in reproduction leading to varying colony attendance with time of the year. Finally, external factors such as climatic oscillations and correlated fluctuations in food abundance may cause breeding lows or highs in some years (Smithers et al. 2003, Monticelli et al. 2007). Failure of a species to reproduce in a given year can in turn reduce its population size in subsequent years and increase that of other species competing with it for nesting space or for food. Additional factors, like cycles of parasite abundance, may render those fluctuations even more complex. For example, extremely high prevalence and individual load of ticks parasitizing Sooty Tern fledglings was reported at Loop in February 1993 (Pandolfi-Benoit 1993), but ticks have seldom been noticed by us since then.

Brown Booby, Red-footed Booby, and Great Frigatebird colonies in the study area were numerically larger than all the other colonies of these species in the whole Coral Sea (Robinet et al. 1997, Pandolfi-Benoit and Bretagnolle 2002, Bourne et al. 2005); the colonies of Wedge-tailed Shearwater ranked second after those of the southern lagoon of New Caledonia (500,000 pairs [Pandolfi-Benoit and Bretagnolle 2002]) and above Herald Cays (>60,000 pairs [Bourne et al. 2005]); and those of Black and Brown Noddies were comparable in size to those of the southern lagoon of New Caledonia and other breeding sites in the Coral Sea (Ogden 1993, Robinet et al. 1997, Pandolfi-Benoit and Bretagnolle 2002, Bourne et al. 2005). The foregoing emphasizes the importance of the Chesterfield-Bampton-Bellona islets as a seabird breeding area for the Coral Sea and for the entire Southwest tropical Pacific.

Recent Changes in Abundance

Both similarities and some changes in the avifauna of the main islets of the Chesterfield group were apparent since the visits by researchers in the 1970s (Rancurel 1973, 1974 *in* Bourne et al. 2005, Condamin 1977). In particular, comparisons can be made between Rancurel's (1973) and Condamin's (1977) visits of Ile Longue and Loop in June 1973 and in October 1977, respectively, and ours in June 2007 and October 2008, respectively. The nesting seabird species remained the same, and no change was apparent in breeding phenology for the three booby species, the Great Frigatebird, the two noddies, and the Sooty Tern. Masked Booby population size has been remarkably stable over the last 30 yr, but it is possible that the population size of Red-footed Boobies has declined recently. A major change was the dramatic increase in the density of nesting Brown Boobies, on both Loop and Ile Longue (Tables 2, 3). Rancurel (1973) noted only a few Brown Boobies nesting at the northern extremity of Ile Longue in June 1973, whereas in June 2007 nesting Brown Boobies occupied at least the entire northern half of the island. Condamin (1977) similarly noted just one Brown Booby nest on Loop in October 1977, whereas in October 2008 dozens were counted. Other apparent changes were the declines in abundance of Fairy Tern and Buff-banded Rail populations (Tables 2, 3). All these changes can hardly be ascribed to interobserver effects.

Thus, no obvious change in population size was apparent over the last three decades, except an increase in Brown Booby and perhaps a decrease in Fairy Tern and in Buff-banded Rail. At the interdecadal scale, pelagic ecosystems have undergone recent changes due to an increase in average temperature (Levitus et al. 2005) and a decline in the abundance of large pelagic fishes (Myers and Worm 2003). One can hypothesize consequences of these changes on the whole trophic chain, including seabird populations (e.g., Byrd et al. 2008), to explain the increase of the Brown Booby population breeding in the Chesterfield Islands.

Threats

Disturbance to nesting Brown Noddies, Sooty Terns, Masked Boobies, and Brown Boobies occurred solely from the presence of visitors passing nearby (10–20 m), prompting the birds to leave their nest. Flushing of

Frigatebirds, either nesting or roosting, was caused by skiffs approaching the beach to land their crew (Borsa and Boiteux 2007). Trampling by visitors damaged Wedge-tailed Shearwater burrows (e.g., we counted an average of eight burrows inadvertently destroyed by each visitor crossing the width of Loop); trampling of Brown Noddy chicks at their nest was also noted (Borsa and Boiteux 2007). Several dozen Frigatebird and Booby chicks are harvested each year by bêche-de-mer fishermen from Nouméa (J. Senia, pers. comm.). Other predators identified were introduced mice, which are apparently abundant on Ile Longue, where they prey on Brown Noddy eggs (Borsa and Boiteux 2007).

Visitors to the Chesterfield Islands currently amount to possibly a few hundred people each year and include fishermen, French Navy crews and accompanying army squads and customs officers, marine scientists, technicians who service the automatic meteorological station on Ilot Loop, yachtsmen, birdwatchers, shell collectors, wreck searchers, moviemakers, and other tourists (Pandolfi-Benoit 1993, 1997, Boisselier et al. 2005, Bourne et al. 2005, Borsa 2006, Borsa and Boiteux 2007, Girard 2008). Given the small surfaces of the islets, the high densities of seabirds, and their vulnerability when nesting, the current level of human disturbance is likely to be substantial. Human disturbance of breeding seabird colonies affects breeding success and adult behavior and can lead to the desertion of the colonies (Erwin 1980, Rodgers and Smith 1995, Carney and Sydeman 1999). For those tern species that nest exclusively on the beach, eggs and young chicks can be inadvertently trampled, and nesting adults are easily flushed by approaching visitors (Pandolfi-Benoit and Bretagnolle 2002).

Another disturbance to seabirds nesting on the Chesterfield Islands formerly consisted of routine monitoring of "migrating birds" for poultry parasites by veterinary services (Beugnet et al. 1993). The methods for detecting internal parasites then required the sacrificing of a number of seabirds from each species (Beugnet et al. 1993); the handling of other birds for external examination led to additional mortalities (M.P., pers. obs.). That program was stopped by the early 1990s, but the recent outbreak of highly pathogenic avian influenza in Southeast Asia (Gauthier-Clerc et al. 2007) has prompted veterinary services in New Caledonia to take steps toward resuming the sanitary control of shorebirds and seabirds on the outer islets, on the assumption that the latter constitute "wildlife reservoirs."

Recommendations

The Chesterfield-Bampton-Bellona reefs and islets, now under the jurisdiction of the New Caledonian government, still do not benefit from any official status that would guarantee habitat and biological conservation. For unknown reasons, they have been excluded from the series of New Caledonian coral reef areas added in 2008 to the UNESCO World Heritage list.

To preserve the seabird populations of the Chesterfield-Bampton-Bellona islands, it is advisable to implement regulations to limit visits and to educate visitors. Although the current level of poaching is low, it should be dissuaded, as should be the questionable disease-monitoring programs (no hard evidence has yet linked the long-distance spread of the avian influenza to wild birds [Butler 2006, Gauthier-Clerc et al. 2007, Feare 2007] and the handling of wild birds may itself increase the risk of spreading other diseases, such as tick-borne arboviruses [W. R. P. Bourne, pers. comm.]). Drastic steps might be necessary to protect sensitive species from disturbance, especially those nesting on the beach. The eradication of Ile Longue's mice (Borsa and Boiteux 2007) should be envisaged. The restoration of the native ligneous vegetation, where needed, should be considered, to stabilize the islets in the face of cyclones and increasing sea level and to provide nesting habitat.

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Literature Cited

Andréfouët, S., G. Cabioch, B. Flamand, and B. Pelletier. 2007. The diversity of New Caledonia coral reef geomorphology and genetic processes: A synthesis from optical remote sensing, coring and multi-beam acoustic observations. Pages 33–49. Doc. Sci. Tech., Sér. II 7. 2nd ed. Institut de recherche pour le développement, Nouméa.

Andréfouët, S., F. E. Müller-Karger, J. A. Robinson, C. J. Kranenburg, D. Torres-Pulliza, S. A. Spraggins, and B. Murch. 2006. Global assessment of modern coral reef extent and diversity for regional science and management applications: A view from space. Pages 1732–1745 *in* Y. Suzuki, T. Nakamori, M. Hidaka, H. Kayanne, B. E. Casareto, K. Nadaoka, H. Yaman, M. Tsuchiya, and K. Yamazato, eds. Proc. 10th Int. Coral Reef Symp., Okinawa, 28 June to 2 July 2004. Japanese Coral Reef Society, Okinawa.

Anonymous. 1916. Australia pilot. Vol. 3. Hydrographic Department, Admiralty, London.

———. 1968. Opération météo aux îles Chesterfield. J. Calédonien 225:4–5.

Ashmole, N. P. 1963. The biology of the Wideawake or Sooty Tern *Sterna fuscata* on Ascension Island. Ibis 103b:297–364.

Beugnet, F., R. Costa, O. Ferré, and V. Marchal. 1993. Statut sanitaire et inventaire de l'avifaune des îlots français du Pacifique Sud: Etude de l'île Surprise. Rev. Méd. Vét. 144:607–613.

Blaber, S. J. M., D. A. Milton, M. J. Farmer, and G. C. Smith. 1998. Seabird breeding populations on the far northern Great Barrier Reef, Australia: Trends and influences. Emu 98:44–57.

Boisselier, M.-C., P. Lozouet, A. Warén, J. Lai, P. Bouchet, and B. Richer de Forges. 2005. Campagne EBISCO du N.O. "Alis" aux îles Chesterfield du 3 au 25 octobre 2005. Institut de recherche pour le développement, Nouméa (Available from IRD Library; pdf version available from P. Borsa).

Borsa, P. 2006. Mission ornithologique aux îles Chesterfield, 12–16 décembre 2005. Institut de recherche pour le développement, Nouméa (Available from IRD, Bondy, France, and IRD Library, Nouméa; pdf version available from http://www.documentation.ird.fr/).

———. 2008. Mission ornithologique à l'îlot Loop (îles Chesterfield) et transects en mer de Corail et dans le bassin des Loyauté, 20–28 octobre 2008. Institut de recherche pour le développement, Nouméa (Available from IRD, Bondy, France, and IRD Library, Nouméa; pdf version available from http://www.documentation.ird.fr/).

———. 2009. Mission ornithologique aux îles Chesterfield à bord du patrouilleur *La Moqueuse*, 26 janvier–1 février 2009. Institut de recherche pour le développement, Nouméa (Available from IRD, Bondy, France, and IRD Library, Nouméa; pdf version available from http://www.documentation.ird.fr/).

Borsa, P., and N. Boiteux. 2007. Recensement des oiseaux marins de l'île Longue (atoll des Chesterfield), 18–22 juin 2007. Institut de recherche pour le développement, Nouméa (Available from IRD, Bondy, France, and IRD Library, Nouméa; pdf version available from http://www.documentation.ird.fr/).

Bourne, W. R. P., A. C. F. David, and I. A. W. McAllan. 2005. The birds of the southern Coral Sea including observations by HMS *Herald* in 1858–60. Atoll Res. Bull. 541: 239–264.

Bretagnolle, V., and M. Pandolfi-Benoit. 1997. Distribution, status and notes on the breeding biology of the bridled tern *Sterna anaethetus* in New Caledonia. Emu 97:310–315.

Butler, D. 2006. Doubts hang over source of bird flu spread. Nature (Lond.) 439:773.

Byrd, G. V., W. J. Sydeman, H. M. Renner, and S. Minobe. 2008. Responses of piscivorous seabirds at the Pribilof Islands to ocean climate. Deep-Sea Res. II 55:1856–1867.

Carney, K. M., and W. J. Sydeman. 1999. A review of human disturbance effects on nesting colonial waterbirds. Colon. Waterbirds 22:68–79.

Cohic, F. 1959. Report on a visit to the Chesterfield Islands, September 1957. Atoll Res. Bull. 63:1–11.

Condamin, M. 1977. Compte rendu de mission aux îles Chesterfield du 29.IX au 7.X.1977. ORSTOM, Nouméa (Available from IRD, Bondy, France, and IRD Library, Nouméa; pdf version available from http://www.documentation.ird.fr/).

de Naurois, R., and P. Rancurel. 1978. Observations nouvelles sur les Laridae reproducteurs en Nouvelle-Calédonie. C. R. Acad. Sci. Paris, Sér. D 287:495–498.

Erwin, M. R. 1980. Breeding habitat use by colonially nesting waterbirds in two Mid-Atlantic U.S. regions under different regimes of human disturbance. Biol. Conserv. 18:39–51.

Feare, C. J. 2007. The spread of avian influenza. Ibis 149:424–425.

Gauthier-Clerc, M., C. Lebarbenchon, and F. Thomas. 2007. Recent expansion of highly pathogenic avian influenza H5N1: A critical review. Ibis 149:202–214.

Girard, H. 2008. Des cônes calédoniens étudiés à Genève. Nouv. Calédoniennes 11330:10.

Higgins, P. J., and S. J. J. F. Davies, eds. 1996. Handbook of Australian, New Zealand and Antarctic birds. Vol. 3. Snipes to pigeons. Oxford University Press, Melbourne.

Jaquemet, S., M. Le Corre, and G. D. Quartly. 2007. Ocean control of the breeding regime of the Sooty Tern in the Southwest Indian Ocean. Deep-Sea Res. I 54:130–142.

Johnstone, R. E. 1982. Distribution, status and variation of the silver gull *Larus novaehollandiae* Stephens, with notes on the *Larus cirrocephalus* species-group. Rec. West. Aus. Mus. 10:133–165.

King, B. R. 1993. The status of Queensland seabirds. Corella 17:65–92.

Levitus, S., J. Antonov, and T. Boyer. 2005. Warming of the world ocean, 1955–2003. Geophys. Res. Lett. 32:L02604.

Marchant, S., and P. J. Higgins, eds. l990. Handbook of Australian, New Zealand and Antarctic birds. Vol. 1. Ratites to ducks. Oxford University Press, Melbourne.

Missègue, F., and J.-Y. Collot. 1987. Etude géophysique du plateau des Chesterfield (Pacifique sud-ouest). Résultats préliminaires de la campagne ZOE 200 du N/O Coriolis. C. R. Acad. Sci. Paris, Sér. II 304:279–283.

Monticelli, D., J. A. Ramos, and G. D. Quartly. 2007. Effects of annual changes in primary productivity and ocean indices on breeding performance of tropical roseate terns in the western Indian Ocean. Mar. Ecol. Prog. Ser. 351:273–286.

Myers, R. A., and B. Worm. 2003. Rapid worldwide depletion of predatory fish communities. Nature (Lond.) 423:280–283.

Ogden, J. 1993. Population increase and nesting patterns of the black noddy *Anous minutus* in *Pisonia* forest on Heron Island: Observations in 1978, 1979 and 1992. Aust. Ecol. 8:395–403.

Pandolfi-Benoit, M. 1993. Mission ornithologique à l'île Loop (février 1993). Province

Sud, Nouméa (Available from Direction de l'environnement, Province Sud, Nouméa, and from P. Borsa).
———. 1997. Rapport de mission ornithologique aux Chesterfield, mai 1997. Province Sud, Nouméa (Available from Direction de l'environnement, Province Sud, Nouméa, and from P. Borsa).
Pandolfi-Benoit, M., and V. Bretagnolle. 2002. Seabirds of the southern lagoon of New Caledonia: Distribution, abundance and threats. Waterbirds 25:202–213.
Rancurel, P. 1973. Compte rendu de mission aux îles Chesterfield du 21 au 28 juin 1973. ORSTOM, Nouméa (Available from IRD, Bondy, France, and IRD Library, Nouméa; pdf version available from http://www.documentation.ird.fr/).
———. 1976. Liste préliminaire des oiseaux de mer des îles et îlots voisins de la Nouvelle-Calédonie. Cah. O.R.S.T.O.M. Ser. Océanogr. 14:163–168.
Robinet, O., S. Sirgouant, and V. Bretagnolle. 1997. Marine birds of d'Entrecasteaux Reefs (New Caledonia, southwestern Pacific): Diversity, abundance, trends and threats. Colon. Waterbirds 20:282–290.
Rodgers, J. A., and H. T. Smith. 1995. Setback distances to protect nesting bird colonies from human disturbance in Florida. Conserv. Biol. 9:89–99.
Schreiber, R. W., and N. P. Ashmole. 1970. Sea-bird breeding seasons on Christmas Island, Pacific Ocean. Ibis 112:363–394.
Smithers, B. V., D. R. Peck, A. K. Krockenberger, and B. C. Congdon. 2003. Elevated sea-surface temperature, reduced provisioning and reproductive failure of wedge-tailed shearwaters (*Puffinus pacificus*) in the southern Great Barrier Reef, Australia. Mar. Freshwater Res. 54:973–977.
Spaggiari, J., N. Barré, J. Baudat-Franceschi, and P. Borsa. 2007. New Caledonian seabirds. Pages 415–428. Doc. Sci. Tech. Sér. II 7. 2nd ed. Institut de recherche pour le développement, Nouméa.
Thiercelin, L. 1866. Journal d'un baleinier: Voyages en Océanie. Vol. 1. Hachette, Paris.