PELAGIC SEABIRD SURVEYS IN THE TUAMOTU AND GAMBIER ARCHIPELAGOS, FRENCH POLYNESIA

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SUMMARY

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We conducted pelagic seabird surveys in the Gambier and Tuamotu Archipelagos in the southeastern Pacific Ocean totaling 40 hours during 7–27 March 2003 and 22.5 hours during 22–27 July 2001. We used a 300-m-wide strip transect to estimate seabird density, and we estimated relative abundance of birds at all distances. In 2001, we observed a total of 326 birds of 18 species. The mean relative abundance of all birds was 14.3 ± 3.1/h. Red-footed Booby *Sula sula* was the most abundant species (5.6/h), followed by White Tern *Gygis alba* (3.4/h), and Great Crested or Swift Tern *Sterna bergii* (1.2/h). In 2003, we observed a total of 1463 birds of 25 species. The mean relative abundance of all birds was 36.6 ± 11.4/h and the mean density of all birds was 4.14 ± 0.72/km^2. Brown Noddy *Anous stolidus* was the most abundant species (17.6/h, 1.5/km^2), followed by White Tern (8.4/h, 1.3/km^2), and Red-footed Booby (4.6/h, 0.8/km^2). Several globally or locally rare species were observed infrequently, including Phoenix Petrel *Pterodroma alba* (0.1/h, 0.03/km^2). Distribution of birds was uneven, with long periods of no birds punctuated by occasional feeding flocks. In 2003, species diversity was related to length of observation period, with more species observed on longer segments ($r^2 = 0.58$, $F_{1,5} = 6.03$, $P = 0.05$). Although the duration and extent of our surveys were limited, these data are valuable because little published information is available on pelagic seabirds in southeastern Polynesia.

Key words: French Polynesia, Gambier Archipelago, Tuamotu Archipelago, pelagic seabirds

INTRODUCTION

The numerous islands of eastern Polynesia provide important breeding sites for many species of seabirds, but little information is available on the distribution or abundance of seabirds at sea in this area (Holyoak & Thibault 1982, 1984; Thibault & Bretagnolle 1999). Extensive surveys have been made of pelagic seabirds in the eastern tropical Pacific (e.g. Pitman 1986, Spear *et al.* 1992, Phillips *et al.* 1995, Spear *et al.* 1995), but no previous quantitative pelagic seabird surveys have been conducted among the island groups of the southeastern Pacific. This is particularly true of the Tuamotu Archipelago, a collection of 76 atolls more than 1500 km in length, and the remote Gambier Islands (Fig. 1).

In July 2001 and March 2003, we undertook expeditions to survey birds on selected islands in the Tuamotu and Gambier Archipelagos. Atolls were selected for surveys based on whether they were uninhabited, the time since the last survey, and the likelihood of their supporting bird populations. Results pertaining to resident land birds, nesting seabirds and migratory waterbirds are presented elsewhere (Pierce *et al.* 2003, Tibbitts *et al.* 2003, VanderWerf *et al.* 2004). Here, we report on the pelagic distribution and abundance of seabirds based on surveys made in transit between islands. This information is useful for understanding the distribution and movement of seabirds and the status and trends of their populations (Gould & Forsell 1989). In particular, this information will facilitate future research and assist with conservation planning for rare seabirds that occur in the study area.

METHODS

We collected information on pelagic seabird abundance during 22.5 h of surveys in July 2001 and 40 h of surveys in March 2003 (Tables 1–3). Survey routes were determined in advance by the locations of atolls selected for surveys, and pelagic observations were made during as many daylight hours as practicable along the route. In 2001, RJP recorded the identity of all of birds seen with the naked eye and with 10×42 binoculars during 10-minute intervals in a 180-degree arc behind the stern of the 60-m trading ship *Nuku Hau.* In 2003, we collected similar data from the flying bridge of the RV *Bounty Bay,* a 15-m, 40-tonne motor catamaran, and we also recorded the identity and behavior of all birds seen during 10-minute intervals in a 300-m-wide strip transect centered on the bow, as prescribed by Tasker *et al.* (1984) and Gould & Forsell (1989). Data on birds recorded within the strip transect were used to estimate density, expressed as birds per km^2. Data on total numbers of birds detected within and outside the strip transect were used to estimate relative abundance, expressed as birds per hour. We calculated mean ± standard error density and relative abundance using the numbers of birds observed during each 10-minute observation period.

In 2003, we recorded the position of the ship every 10 minutes with a hand-held global positioning system unit, and during each 10-minute observation period we also recorded the following information:

- Ship's course and speed
- Observation conditions (excellent, good, fair, poor)
- Sea state
- Species of each bird
- Bird behavior (feeding, sitting, flying)
- Direction of flight
- Any associated bird species

The ship's speed averaged 12.5 km/h (range: 7.4–13.6 km/h) during our observations, so that the area covered during the 10-minute periods averaged 0.62 km^2 (range: 0.37–0.68 km^2). Because of the presence of breeding birds, the number of birds observed close to atolls was often high, and so we discontinued surveys when an atoll became visible on the horizon (*c.* 10 km away) to avoid overestimating pelagic abundance. Exceptions occurred in 2001 at Reao, where several gadfly petrels *Pterodroma* sp. were observed close to land, and at Nengonengo. All birds were identified to species based on information in Harrison (1987), Pratt *et al.* (1987), Roberson & Bailey (1991) and Spear *et al.* (1992). However, some gadfly petrels could only be identified to genus in 2003 (Table 2).

Coastline data at a 1:250 000 scale were downloaded from the U.S. National Oceanographic and Atmospheric Administration's National Geophysical Data Center (rimmer.ngdc.noaa.gov/mgg/coast/getcoast.html). Digital maps were accurate to within 500 m at this scale.

RESULTS AND DISCUSSION

In July 2001, we observed a total of 326 birds of 18 species during 22.5 hours of observation (Table 1). The mean relative abundance of all birds was 14.3 ± 3.1/h. Red-footed Booby *Sula sula* was the most abundant species (5.6/h), followed by White Tern *Gygis alba* (3.4/h), and Great Crested or Swift Tern *Sterna bergii* (1.2/h).

In March 2003, we observed a total of 1463 birds of 25 species during 40 hours of observation, of which 623 were within the 300-meter-wide transect (Tables 2 and 3). The mean relative abundance of all birds was 36.6 ± 11.4/h, and the mean density of all birds within the 300-m-wide transect was 4.14 ± 0.72/km^2. Brown Noddy *Anous stolidus* was the most abundant species in 2003 (17.6/h, 1.5/km^2), followed by White Tern (8.4/h, 1.3/km^2) and Red-footed Booby (4.6/h, 0.8/km^2). Most species were observed infrequently, and some were observed only outside the 300-m-wide transect, so that no density estimate was possible (Table 3).

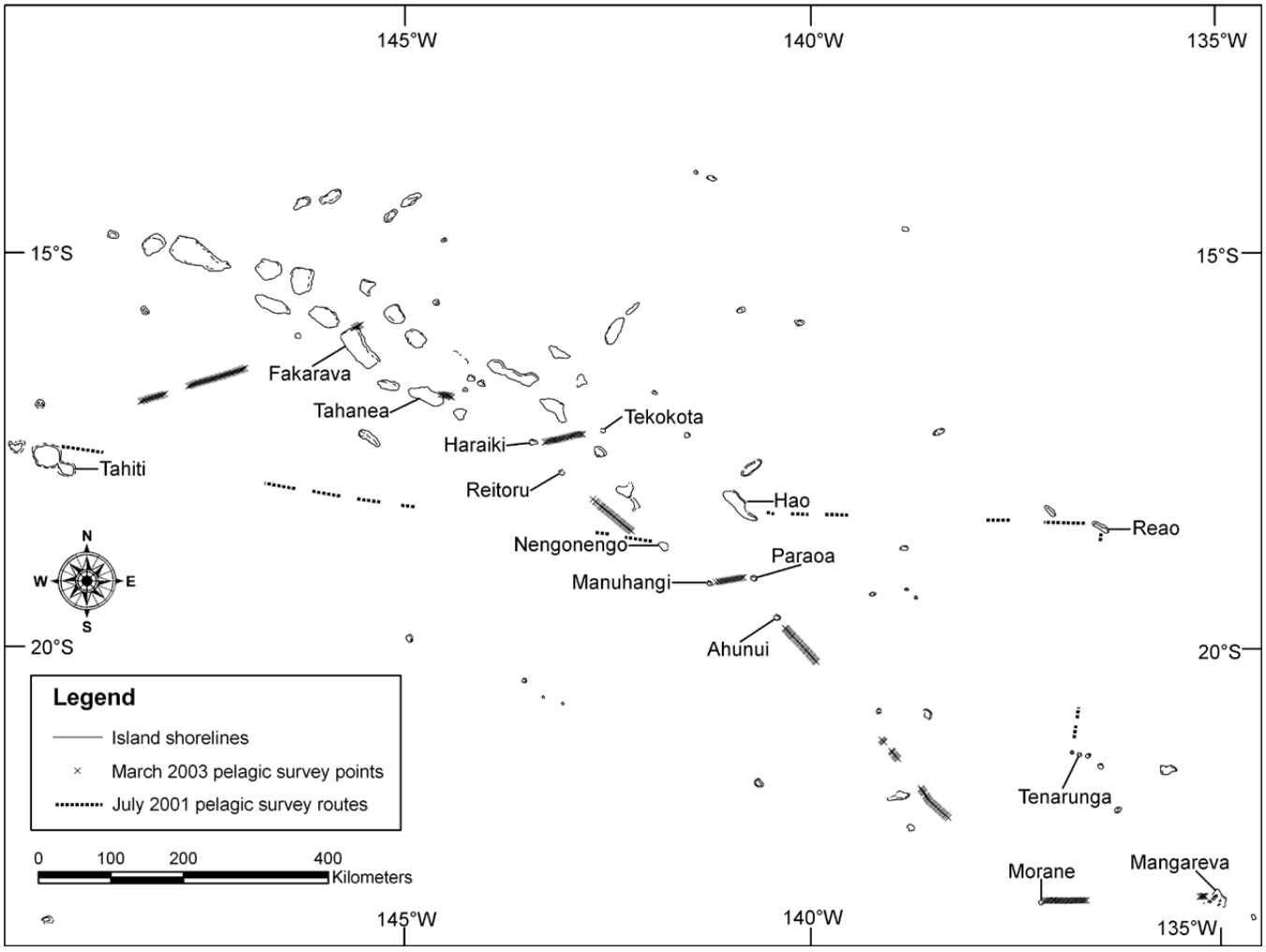

Fig. 1. Locations of pelagic seabird surveys among islands in the Tuamotu and Gambier archipelagos, southeastern Pacific Ocean in 2001 and 2003. Only islands that were surveyed are labeled.

The distribution of birds was uneven; long periods with no birds were punctuated by occasional feeding flocks that accounted for a large proportion of all birds observed. In 2003, no birds were observed during 82 of the 240 10-minute observation periods. The largest feeding flock, seen just west of Mangareva, contained approximately 390 birds.

Our density estimates are likely to be fairly accurate for the more abundant and larger species because the strip transect was fairly narrow and observation conditions were generally good to excellent. We probably saw a large proportion of the birds within the transect. However, our density estimates for rare species are imprecise because of small sample sizes and high variances. Our

TABLE 1
Relative abundance (birds/h) of seabird species recorded during pelagic surveys in the Tuamotu Archipelago, July 2001 [a]

Details	Tenarunga–Reao	Near Reao	Reao–Hao	Nengonengo–Tahiti	Near Tahiti	Total (mean±SE)
Date, search time (h:min)	22 July, 1:50	23 July, 4:50	24 July, 2:50	25–26 July, 9:50	27 July, 3:10	22:30
Black-winged Petrel *Pterodroma nigripennis*		2.69			0.32	0.61±0.29
Collared Petrel *P. leucoptera brevipes*				0.10	0.95	0.17±0.14
Phoenix Petrel *P. alba*				0.10		0.04±0.04
Tahiti Petrel *P. rostrata*				1.08	3.79	1.00±0.24
Murphy's Petrel *P. ultima*	1.64					0.13±0.10
Audubon's Shearwater *Puffinus lherminieri*					1.58	0.22±0.16
Red-tailed Tropic Bird *Phaethon rubricauda*				0.29		0.13±0.10
White-tailed Tropic Bird *P. lepturus*					0.32	0.04±0.04
Masked Booby *Sula dactylatra*				0.10		0.04±0.04
Brown Booby *S. leucogaster*					0.63	0.09±0.06
Red-footed Booby *S. sula*	1.09	0.21	2.83	5.60	18.93	5.61±2.28
Lesser Frigatebird *F. ariel*		0.62				0.13±0.08
Greater Frigatebird *F. minor*	1.09	1.45	0.35	0.29	0.63	0.66±0.22
Great Crested Tern *Sterna bergii*		0.41	0.35	0.10	7.26	1.18±0.58
Gray-backed Tern *S. lunata*		0.21				0.04±0.04
Black Noddy *Anous minutus*	0.55		0.35	0.29		0.22±0.11
Brown Noddy *A. stolidus*		0.21			3.79	0.57±0.44
White Tern *Gygis alba*		1.66	3.89	3.93	5.68	3.37±0.74
All Species	**4.37**	**7.45**	**7.77**	**11.90**	**43.85**	**14.28±3.12**

[a] See Fig. 1 for survey locations.

TABLE 2
Summary of pelagic surveys conducted in the Tuamotu and Gambier Archipelagos, March 2003 [a]

Details	Mangareva–Morane	Morane–Ahunui	Paraoa–Manuhangi	Manuhangi–Reitoru	Haraiki–Tekokota	Haraiki–Tahanea	Fakarava–Moorea	Total
Date, time searching (h:min)	7–8 March, 5:40	11–12 March, 12:00	15 March, 2:50	16 March, 5:20	19 March, 4:00	22 March, 1:30	27 March, 8:40	40:00
Latitude (start–end)	23°05′S–23°09′S	22°07′S–19°46′S	19°08′S–19°11′S	18°34′S–18°10′S	17°27′S–17°22′S	16°53′S–16°52′S	16°32′S–16°57S	23°05′S–16°54′S
Longitude (start–end)	135°05′W–137°05′W	138°17′W–140°18′W	140°49′W–141°10′W	142°13′W–142°41′W	143°17′W–142°49′W	144°26′W–144°35′W	147°01′W–148°19′W	135°05′W–148°19′W
Distance (km)	63.5	142.7	38.8	70.1	53.3	16.6	116.5	501.5
Total species observed	10	12	6	8	5	9	12	25
Total individuals observed	493	321	108	153	146	60	182	1463

[a] Latitude and longitude recorded by a global positioning system device in WGS84 and expressed in degrees and minutes. See Fig. 1 for survey locations.

TABLE 3

Density and abundance of bird species recorded during pelagic surveys in the Tuamotu and Gambier Archipelagos, March 2003 [a]

Species	Density/ Abundance	Mangareva–Morane	Morane–Ahunui	Paraoa–Manuhangi	Manuhangi–Reitoru	Haraiki–Tekokota	Haraiki–Tahanea	Fakarava–Moorea	Total (mean±SE)
Black-winged Petrel *Pterodroma nigripennis*	(birds/km^2)							0.03	0.007±0.007
	(birds/h)							0.11	0.03±0.03
Juan Fernandez Petrel *P. externa*	(birds/km^2)				0.05				0.007±0.007
	(birds/h)				0.19			0.11	0.05±0.04
Herald Petrel *P. arminjoniana*	(birds/km^2)							0.03	0.007±0.007
	(birds/h)	0.18						0.23	0.08±0.04
Kermadec Petrel *P. neglecta*	(birds/km^2)		0.02						0.007±0.007
	(birds/h)		0.08						0.03±0.03
Phoenix Petrel *P. alba*	(birds/km^2)		0.02		0.05		0.40		0.03±0.02
	(birds/h)		0.08		0.19		1.33		0.10±0.06
Tahiti Petrel *P. rostrata*	(birds/km^2)	0.05		0.17				0.52	0.14±0.04
	(birds/h)	0.18		0.71		0.25		3.58	0.88±0.21
Murphy's Petrel *P. ultima*	(birds/km^2)		0.02						0.007±0.007
	(birds/h)		0.08						0.03±0.03
Gadfly petrels *Pterodroma* sp.	(birds/km^2)							0.06	0.08±0.04
	(birds/h)							0.46	0.10±0.05
Wedge-tailed Shearwater *Puffinus pacificus*	(birds/km^2)		0.07		0.10			0.17	0.07±0.02
	(birds/h)	1.8	0.33		0.56			0.93	0.63±0.27
Sooty Shearwater *P. griseus*	(birds/km^2)		0.07						0.02±0.02
	(birds/h)		0.33						0.10±0.07
Short-tailed Shearwater *P. tenuirostris*	(birds/km^2)							0.20	0.05±0.02
	(birds/h)							1.61	0.35±0.13
Christmas Shearwater *P. nativitatis*	(birds/km^2)		0.05	0.77		0.19			0.09±0.04
	(birds/h)	1.8	0.17	3.89		0.75			0.65±0.30
Audubon's Shearwater *P. iherminieri*	(birds/km^2)								0
	(birds/h)	10.8	0.08						1.55±1.50
Little Shearwater *P. assimilis*	(birds/km^2)						0.20		0.007±0.007
	(birds/h)						0.67		0.03±0.03
Polynesian Storm Petrel *Nesofregetta fuliginosa*	(birds/km^2)								0
	(birds/h)		xxby						xxby
Red-tailed Tropicbird *Phaethon rubricauda*	(birds/km^2)	0.05			0.05				0.01±0.01
	(birds/h)	0.18		0.35	0.19				0.08±0.04
White-tailed Tropicbird *P. lepturus*	(birds/km^2)							0.03	0.007±0.007
	(birds/h)							0.11	0.03±0.03
Masked Booby *Sula dactylatra*	(birds/km^2)								0
	(birds/h)	0.18					0.67		0.05±0.04
Brown Booby *S. leucogaster*	(birds/km^2)		0.05				0.20		0.02±0.02
	(birds/h)		0.17				2.0	0.11	0.15±0.08
Red-footed Booby *S. sula*	(birds/km^2)	0.58	0.51	0.17	0.24	3.19	1.00	0.66	0.79±0.24
	(birds/h)	3.0	4.75	4.24	2.44	13.0	4.0	3.23	4.63±1.20
Lesser Frigatebird *Fregata ariel*	(birds/km^2)						0.20		0.007±0.007
	(birds/h)						0.67		0.03±0.03
Greater Frigatebird *F. minor*	(birds/km^2)								0
	(birds/h)							0.11	0.03±0.03
Great Crested Tern *Sterna bergii*	(birds/km^2)				0.05				0.007±0.007
	(birds/h)				0.19				0.03±0.03
Black Noddy *Anous minutus*	(birds/km^2)						1.81		0.06±0.04
	(birds/h)						6.0		0.23±0.13
Brown Noddy *A. stolidus*	(birds/km^2)	0.26	0.33	0.52	3.61	4.13	4.02	1.12	1.50±0.40
	(birds/h)	36.2	18.25	14.49	16.32	16.75	15.33	7.27	17.63±7.08
Common White Tern *Gygis alba*	(birds/km^2)	4.41	0.49	0.43	1.57	1.44	2.61	0.37	1.28±0.21
	(birds/h)	32.9	2.0	7.42	8.63	5.75	9.33	2.31	8.35±2.70
Unidentified bird sp.	(birds/km^2)							0.03	0.03±0.03
	(birds/h)		0.42	7.07				0.81	0.80±0.52
All species	**(birds/km2)**	**5.35**	**1.64**	**2.06**	**5.71**	**8.94**	**10.44**	**3.20**	**4.14±0.72**
	(birds/h)	**87.1**	**26.75**	**38.16**	**28.71**	**36.50**	**40.0**	**21.0**	**36.6±11.4**

[a] Density estimates are based on birds observed within a 300-m-wide transect; abundance estimates are based on all birds seen. An "x" indicates that the species was seen, but not during standardized observation periods, and no abundance estimate was possible.

relative abundance estimates are likely to be biased in favor of larger species and those that are more visible at a distance, such as boobies and White Terns, but they nevertheless provide a useful index of abundance for comparison with other studies.

The diversity of seabirds observed was high (27 species for the two surveys), but abundance was low, which is typical of tropical seas (Harrison 1990, Ballance & Pitman 1999). Species number in 2003 was related to length of observation, with more species observed on longer segments ($r^2 = 0.58$, $F_{1,5} = 6.03$, $P = 0.05$), suggesting that the shorter segments did not provide an adequate sample of diversity. Although the duration and extent of our surveys were limited, these data represent one of the few quantitative assessments of distribution and abundance of pelagic birds in the region (Holyoak & Thibault 1982, 1984; Thibault & Bretagnolle 1999).

The species observed most frequently during pelagic surveys (Brown Noddy, White Tern and Red-footed Booby) were also the most abundant breeding species on nearby atolls (Pierce *et al.* 2003). However, several other species that we knew were breeding on nearby atolls were observed only rarely at sea. These included Brown Boobies *Sula leucogaster* on Tahanea and Fakarava, Greater *Fregata minor* and Lesser *F. ariel* Frigatebirds on Reitoru and other atolls, Murphy's Petrels *P. ultima* in the Acteon Group and Reitoru, Grey-backed Terns *Sterna lunata* on several atolls, and Masked Boobies *Sula dactylatra* and Kermadec Petrels *P. neglecta* on Morane (Pierce *et al.* 2003). For species that typically forage close to islands, the scarcity of pelagic sightings probably reflects this behavior (Manu 1999). For example, Black Noddies *A. minutus* were abundant breeders on several atolls, but we rarely saw them more than a few kilometers from shore. Similarly, Great Crested Terns were frequently observed within sight of islands, particularly Tahiti, but were rarely encountered during pelagic surveys. For the other species, however, such as gadfly petrels, the scarcity of pelagic sightings probably reflects their rarity in the Tuamotu Archipelago.

Several of the species we observed are globally or locally rare, and thus information from these pelagic surveys may be important to their conservation by helping to direct surveys for nesting areas where management could be implemented. The Phoenix Petrel *P. alba* is reported to breed in the Tuamotu Archipelago (del Hoyo *et al.* 1992), but recent surveys in several island groups have failed to locate nesting sites (Pierce *et al.* 2003), and there is considerable concern about this species (BirdLife International 2000, USFWS 2004). We observed four Phoenix Petrels in March 2003 and one in July 2001, in widely scattered locations (Fig. 1, Tables 1 and 3). Two of these birds were distinguished from the more-numerous Tahiti Petrel *P. rostrata* by the presence of a pale throat patch, the others by their smaller size, wing shape and more buoyant, arcing flight (Spear *et al.* 1992). We observed a single Polynesian Storm-Petrel *Nesofregetta albogularis* near Morane, although the closest known breeding colonies of this species are 200 km away on Manui and possibly Motu Teiku in the Gambier Islands (Thibault & Bretagnolle 1999, R. Pierce pers. obs.). We observed a single Little Shearwater *Puffinus assimilis* flying south near Tahanea on 22 March 2003. The only known breeding colonies of this species in southeastern Polynesia are on islets off Rapa in the Austral Islands (Holyoak & Thibault 1984), and the bird was flying in that direction.

We observed several species of shearwaters and petrels that are not known to breed locally and presumably were on migration, including 14 Short-tailed Shearwaters *P. tenuirostris* flying north on 27 March between Fakarava and Moorea, and 12 Sooty Shearwaters *P. griseus* flying northwest on 12 March between Morane and Ahunui. There are few previous reports of either species in eastern Polynesia. A single specimen of the Short-tailed Shearwater was collected in the Tuamotu Archipelago on 25 November 1906 (Holyoak & Thibault 1984). Sooty Shearwaters have not been observed previously in the Tuamotu Archipelago, but this is likely attributable to the lack of surveys. They were noted around Tahiti and the Marquesas in May 1958 (King 1967) and between Rurutu and Rapa in the Austral Islands from 20 March to 13 April 1921. Single specimens were collected on Tahiti on 13 December 1971 (Holyoak & Thibault 1984) and November 1995 (P. Raust pers. comm.). Short-tailed Shearwaters breed in southeastern Australia from September to April (Lindsey 1986); Sooty Shearwaters breed mainly on islands off New Zealand, Tasmania and Chile and in the Falkland Islands September–May (del Hoyo *et al.* 1992). After breeding, both species embark on a clockwise migration around the Pacific, in which most individuals are thought to travel northward through the western Pacific and southward through the central and eastern Pacific (Lindsey 1986, Harvey *et al.* 2004). Collectively, these observations indicate that some individuals of each species, perhaps prebreeders that leave breeding sites early, pass northward through eastern Polynesia.

In 2003 we observed several small gadfly petrels between Fakarava and Moorea that probably were either Black-winged *P. nigripennis* or Collared Petrels (Table 1; Spear *et al.* 1992). Collared Petrels were observed in sight of the east and north coasts of Tahiti in July 2001 by RJP.

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