

The Critically Endangered Mascarene Petrel *Pseudobulweria aterrima*: identification and behaviour at sea, historical discovery of breeding sites, and breeding ecology on Réunion, Indian Ocean

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SUMMARY.—Results from pelagic expeditions to study Mascarene Petrel *Pseudobulweria aterrima* off Réunion, Indian Ocean, in December 2012, are presented. At-sea identification features, flight characters and feeding behaviour are described, as well as comparisons with confusion taxa. Adult plumage, the least known, is described in detail. Photographs, believed to be the first of this species taken at sea, are presented. One shows a female with an egg inside her body, providing evidence of return from pre-laying exodus and adding to understanding of the breeding cycle. Thirty-three individuals were recorded during three days at sea. Nine presumed breeding burrows, at six different sites, were found on Réunion in 1997–99 and the background to this significant discovery is included, together with an updated population estimate for this elusive species.

The Critically Endangered Mascarene Petrel *Pseudobulweria aterrima* is one of the least known of the world's Procellariiformes (e.g. Brooke 2004, Gangloff *et al.* 2012). Recent molecular work (Bretagnolle *et al.* 1998, Gangloff *et al.* 2012) confirmed *P. aterrima* as a distinct species within the genus *Pseudobulweria*, which comprises four extant species, including the Critically Endangered Fiji Petrel *P. macgillivrayi*, Critically Endangered Beck's Petrel *P. becki*, and Near Threatened Tahiti Petrel *P. rostrata*. The genus is sister to *Puffinus* and *Calonectris* shearwaters, which in turn are most closely related to *Bulweria* and *Procellaria*. It is not closely related to *Pterodroma* petrels as was expected (Imber 1985, Gangloff *et al.* 2012).

Bonaparte described Mascarene Petrel in 1856 as *Procellaria aterrima*, naming it for its black plumage (Jouanin 1970). As a breeder it is endemic to Réunion. A sub-fossil mandible of unknown age was discovered on Rodrigues, Mauritius, 836 km east of Réunion (Bourne 1968) and a roadkill was found in Black Gorges National Park, Mauritius in 2002 (Tatayah *et al.* 2011).

Ten specimens were collected on Réunion in the 19th century (1825–1890, of which just four still exist), but the species was then 'lost' for 80 years until two more were collected, in 1970 and 1973 (Bourne 1965, Jouanin 1970, 1987, Attié *et al.* 1997). Attié *et al.* (1997) listed 31 birds seen at sea between 1978 and 1995 though only ten were considered 'certain' and none was photographed. In 1995 another bird, freshly dead after being hit by a vehicle, was found (Attié *et al.* 1997).

In 1997, VB discovered a colony of *P. aterrima* on Réunion. Attié *et al.* (1997) estimated the total population at <1,000 individuals (range 181–1694 from statistical modelling using at-sea records) and the breeding population to be 250 pairs (range 45–400; assuming that breeders constitute c.25% of total population). French conservation and biological institutes have been involved with various protection measures, e.g. searching for breeding sites and, importantly, rescue and release, where possible, of birds disoriented and grounded by artificial lights (Le Corre *et al.* 1999, 2002, 2003, Riethmuller *et al.* 2012). This has resulted in



Figure 1. Adult Mascarene Petrel *Pseudobulweria aterrima*, off Réunion, December 2012; note unique jizz of heavy bill, well-projecting neck and head, long posterior body, graduated tail, and long slender almost even-width wings with rounded tips (Hadoram Shirihai, © Tubenoses Project)



Figure 2. Adult Mascarene Petrel *Pseudobulweria aterrima*, off Réunion, December 2012; note characteristic head shape, deep bill and tapering posterior body (Hadoram Shirihai, © Tubenoses Project)

25 being rescued in 1996–2010 (Riethmuller *et al.* 2012) with another three in 2011 (Kohler *et al.* 2012). Despite the existence of specimens, and that live birds have been grounded, it is only relatively recently that the species' morphometrics have been detailed (Attié *et al.* 1997, Riethmuller *et al.* 2012).

Following our success in studying Beck's Petrel in the Bismarck Sea, Papua New Guinea (Shirihai 2008), and Fiji Petrel off Gau, Fiji, western Polynesia (Shirihai *et al.* 2009), we decided to apply proven techniques off Réunion, to locate Mascarene Petrel. HS, TP & MSR have field experience with all four *Pseudobulweria* and their confusion species, which makes us uniquely placed to comment on the at-sea identification of Mascarene Petrel, and the difficulty in separating it from other dark petrels.

Riethmuller *et al.* (2012) stated that 18 adults, 12 juveniles and six birds of indeterminate age were collected or grounded in 1834–2010, although photographs of 4–6 different grounded birds available to us were all fledged juveniles. The physical appearance of adults / immatures is least known, therefore we describe these plumages and provide guidance for ageing. Because Mascarene Petrel is generally an 'almost nondescript all-dark petrel', aspects of its shape and proportions, flight modes and behaviour, e.g. foraging techniques, are of major importance for identification.

Our observations confirm that structurally and behaviourally Mascarene Petrel belongs within the genus *Pseudobulweria* and that it shares several features with its congeners; the smaller-sized dark-plumaged *P. macgillivrayi*, the almost similarly sized but white-bellied *P. becki*, and the distinctly larger and white-bellied *P. rostrata* (Fig. 3). Measurements of the four *Pseudobulweria* appear in Table 1.



Figure 3. Specimens of the four extant *Pseudobulweria* petrels, from largest to smallest: Tahiti *P. rostrata* (left), Beck's *P. becki*, Mascarene *P. aterrima* and Fiji Petrels *P. macgillivrayi*; for information concerning the Beck's specimen see Shirihi (2008), for the Mascarene specimen see Bourne (1965) and the Fiji Petrel specimen see Shirihi et al. (2009) (Hadoram Shirihi, © Natural History Museum, Tring)

TABLE 1

Measurements of the four species of *Pseudobulweria*. *P. aterrima* specimens were measured by VB, live bird measurements (') from Riethmuller et al. (2012). All measurements of other species by VB. Wing length = chord, culmen = tip to feathers, bill depth at hook. Specimens at AMNH (New York), UMZC (Cambridge), RMNH (Leiden), MHNR (Réunion), MNHN (Paris), AMS (Sydney), NMNZ (Wellington), BMNH (Tring), FM (Suva). Museum acronyms explained in Acknowledgements.

Sample sizes given in first column, and shown in other columns only where different.							
<i>P. aterrima</i>		Wing length	Tarsus	Culmen	Bill depth	Tail	Mass
Adult	Specimens	238.4 ± 8.4 (8)	39.6 ± 2.15	28.1 ± 2.0	11.4 ± 1.0 (6)	100.4 ± 6.0	222 ± 14.1 (2)
	Live birds ¹	245.6 ± 8.3 (14)	39.7 ± 1.13	27.7 ± 1.27	10.7 ± 0.8 (13)	106.4 ± 7.7	221.5 ± 28.1 (13)
Fledglings	Live birds ¹	243.7 ± 10.5 (15)	39.9 ± 1.10	27.6 ± 1.17	10.3 ± 0.54 (14)	106.7 ± 9.4 (6)	213.3 ± 29.4
<i>P. becki</i>	Specimens	244.7 ± 5.7 (3)	37.9 ± 1.42	26.8 ± 2.02	10.4 ± 2.31	100.3 ± 0.58	-
<i>P. macgillivrayi</i> (adults and one fledgling)	Specimens and live birds	215.8 ± 9.43 (4)	36.4 ± 0.51 (3)	25.7 ± 1.14	10.2 ± 1.81 (3)	87.5 ± 5.06	131.5 ± 16.26 (2)
<i>P. rostrata</i> (adults)	Specimens	294.8 ± 7.08 (43)	48.0 ± 1.98	35.9 ± 1.34	14.4 ± 0.67	119.6 ± 4.64	374.2 ± 23.3 (6)

TABLE 2
Summary results of pelagic field work, off Réunion, Indian Ocean, 17, 18, 22 December 2012.

	17 Dec 2012	18 Dec 2012	22 Dec 2012
Mascarene Petrels seen	2	14	17
Period chumming	2 hours	3.5 hours	3.25 hours
Location	21°34.005'S, 55°24.960'E 15 nm from St Pierre	21°42.586'S, 55°21.648'E 25 nm from St. Pierre	21°42.586'S, 55°21.648'E 25 nm from St. Pierre
Sea conditions	Beaufort 2 / 3 light to gentle breeze creating wavelets	Beaufort 2–4 light to moderate breeze creating small waves	Beaufort 4 / 5 moderate to fresh breeze creating moderate waves
Other species seen	See Table 4		

Methodology

The same approach to our previous expeditions, searching for Beck's Petrel in 2007 and Fiji Petrel in 2009, was followed. Finding Mascarene at sea, like these petrels, was not by chance but was fully researched in advance. From our experience working with the other *Pseudobulweria* (HS, TP, MSR; see Shirihai 2008, Shirihai *et al.* 2009), and Zino's Petrel *Pterodroma madeira* in Madeira (Shirihai 2009), we had developed a tested method for deciding on sea positions to deploy the chum, to attract petrels close to the boat.

Timing.—Expedition dates were 17 December 2012 to 1 January 2013. Three days were spent at sea, 17, 18 and 22 December 2012, though more were originally allowed. We concur that the species breeds during the austral summer on Réunion (<http://birdlife.org/datazone/speciesfactsheet.php?id=3878>; Le Corre 1999, Le Corre *et al.* 1999, 2002, Riethmuller *et al.* 2012) with an incubation period during October to January (but see Breeding ecology).

Chumming.—Our objective was to observe the birds attracted, and gather data on identification and behaviour of Mascarene Petrel. Large frozen blocks of chum were used, prepared on Réunion ahead of our arrival and kept in cold storage. Each block weighed *c.* 25 kg, the maximum manageable size, and comprised 70% grained or cut fish offal with oil, and 30% fresh water; this was frozen then cut using a mechanical ice saw. We had refined and perfected the mix on previous expeditions, where it was found that floating blocks are highly attractive to tubenoses. Frozen blocks allow the offal to float longer, permitting petrels to take the food before it sinks, whilst creating a pungent and constant oil slick, the aroma being pushed downwind to petrels some miles away. One or two blocks were dropped overboard at hourly intervals.

Study area.—The tropical Indian Ocean island of Réunion (21°08'S, 55°32'E) lies 675 km east of Madagascar and 170 km south-west of Mauritius, the nearest island (Fig. 4). An overseas department of France, it has a population of >837,000 people, the vast majority in the coastal lowlands. The island is 63 km long and 45 km wide. It is mainly mountainous, dominated by two volcanos, one active, and four calderas. These forested highlands have many canyons and cliff faces where Barau's Petrels *Pterodroma barau* and Tropical Shearwaters *Puffinus bailloni* breed, and Mascarene Petrels have long been suspected of doing so, with calling birds confirmed. In Creole villages, like Grand Bassin, the legend of the *Timise*, an imaginary black flying creature that emits chilling nocturnal screams, is now known to relate to Mascarene Petrels (VB pers. obs.; Riethmuller *et al.* 2012).

Information on breeding locations was known to VB, while Riethmuller *et al.* (2012) showed historical locations of grounded birds. Also, we considered the location of Réunion in relation to neighbouring islands and the direction of prevailing winds. The latter are

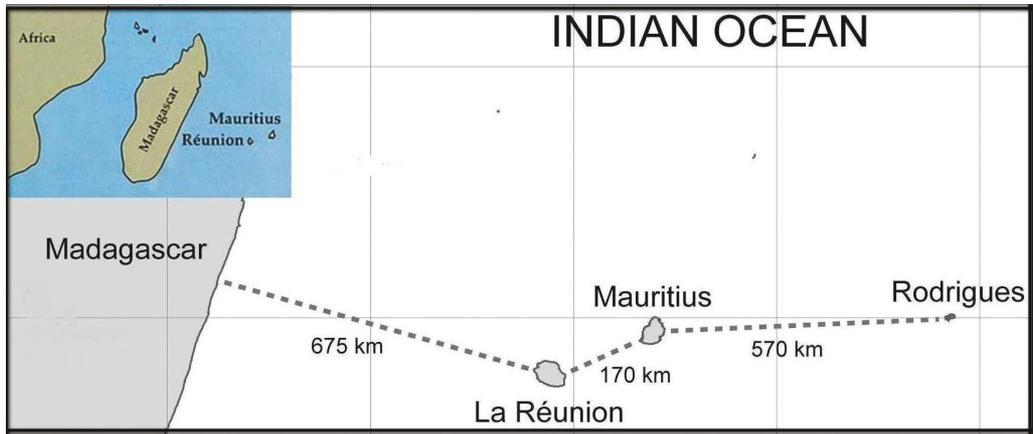


Figure 4. Geographic position of Réunion, Indian Ocean.



Figure 5. Study area: at-sea GPS positions where Mascarene Petrels *Pseudobulweria aterrima* were recorded by us (red). Most were heading towards land as dusk approached. Position 1: two on 17 December 2012. Position 2: 14 birds on 18 December 2012 and 17 on 22 December 2012. Approximate locations of calling birds marked purple. The vast majority of birds grounded (21 of 30; 70% of those in 1970–2010) were in the area shaded yellow (see Riethmuller *et al.* 2012). Satellite images courtesy of Google Inc. All rights reserved © 2013 DigitalGlobe.

TABLE 3

Mean wingspan, body lengths and weights of tubenose species frequenting Réunion waters; in declining order from heaviest in mass. Data from Attié *et al.* (1997), Brooke (2004) and Onley & Scofield (2007).

	Wingspan (cm)	Body length (cm)	Weight (g)
Great-winged Petrel <i>Pterodroma macroptera</i>	97	39	587
Wedge-tailed Shearwater <i>Ardenna pacifica</i>	98	45	415
Barau's Petrel <i>Pterodroma baraui</i>	96	38	400
Trindade Petrel <i>Pterodroma arminjoniana</i>	99	38	393
Mascarene Petrel <i>Pseudobulweria aterrima</i>	88	35	222
Tropical Shearwater <i>Puffinus bailloni</i>	69	31	217
Jouanin's Petrel <i>Bulweria fallax</i>	79	31	173
Bulwer's Petrel <i>Bulweria bulwerii</i>	67	27	100

relevant to seabird flight dynamics, and was coincidentally the same as in Fiji. We deduced that birds would arrive from the south or south-west aided by the south-easterly wind. Records at sea, in Attié *et al.* (1997), appeared to largely confirm this. We concentrated effort south-southwest of the island, and chummed 15 nautical miles (21°34.005'S, 55°24.960'E) and 25 nm (21°42.586'S, 55°21.648'E) from the fishing port of St. Pierre (Fig. 5).

Vessel.—Our base was at Grand Bois in southern Réunion, close to St. Pierre from where we travelled to the survey area in a privately chartered 10-m sports-fishing boat.

Camera equipment and GPS.—Canon EOS-1DX camera body, and 300 mm / F2.8 and 500 mm / F4 lenses. We used a mobile GPS, Garmin Colorado 300 with a marine chart programme, to waymark positions, travel between locations, and log sightings.

Data collection.—Usually the boat drifted just off the chum 'slick', permitting birds to move freely along the slick and to feed undisturbed, while affording us the best angle for observing birds already attracted and incoming. We counted birds and noted activity during sessions of 30–60 minutes. For each species the estimated number of birds during the session and the maximum number seen at one time were recorded. For consistency, the same observer made all counts. These counts were relevant to commoner species found in these waters, especially Barau's Petrel, Wedge-tailed Shearwater *Ardenna pacifica* and Tropical Shearwaters and, most importantly, can be directly compared to the numbers of Mascarene Petrel in any period. At the end of each day we agreed conservative totals. This method is the same as that used in Papua New Guinea, Fiji, Vanuatu, Madeira and Cape Verde (Shirihai 2008, Shirihai *et al.* 2009, 2010, Shirihai & Bretagnolle 2010, Bretagnolle & Shirihai 2011) where counts during chumming were used to monitor numbers of rarer species vs. commoner ones. Each Mascarene Petrel seen was afforded a number (with individual description, behavioural notes and photographic record) used in the analyses below. The three observers (HS, TP, MSR) had appropriate field skills to identify the region's seabirds, and had studied tubenoses at sea over many years, but for any record of rare species, including Mascarene Petrel, the record had to be unanimously considered certain.

Thirty-three Mascarene Petrels were observed, 12 of them photographed. All other petrels seen during the expedition are recorded in Table 4.

TABLE 4
 Petrel species seen during field work off Réunion, Indian Ocean. For scientific names see Table 3.

	17 Dec 2012	18 Dec 2012	22 Dec 2012
Great-winged Petrel			1
Barau's Petrel	>100	300	120
Mascarene Petrel	2	14	17
Wedge-tailed Shearwater	>100	40	50
Tropical Shearwater	>200	50	30
Bulwer's Petrel	1	12	20
Jouanin's Petrel	1	1	1
Wilson's Storm Petrel		1	1
Matsudaira's Storm Petrel		1	

Results

Mascarene Petrel sightings.—Times are local (GMT + four hours). See Table 4 for all species and their numbers. **17 December**—Two together [MP#1, MP#2: photographed] at 19.10–19.15 h, at 21°34.005'S, 55°24.960'E (c.15 nm from St. Pierre). Despite sea conditions being very calm with little wind, i.e. usually unsuitable for viewing gadfly petrels, many were seen (Tables 2, 4). No tubenose showed interest in the well-laid chum trail until, late in the day, a lone Jouanin's Petrel *Bulweria fallax*, followed by a single Bulwer's Petrel *B. bulwerii*, visited the slick, then two Mascarene Petrels. **18 December**—Fourteen during 3.5 hours of chumming, with one remaining for 40 minutes. It was the only species to take any floating morsels. Approaches to the chum; singles at 15.47–15.53 h [MP#3: photographed], 16.11–16.51 h [MP#4: photographed], 17.10–17.15 h [MP#5], 17.21–17.24 h [MP#6], 17.30–17.35 h [MP#7], 17.45 h [MP#8]; then an influx from 18.14 h with singles at 18.14–18.21 h [MP#9: photographed], 18.30 h [MP#10], 18.37 h [MP#11], 18.44 h [MP#12: photographed], two at 18.48–18.53 h [MP#13: photographed, MP#14], two at 19.06–19.15 h [MP#15, MP#16: photographed]. All were at 21°42.586'S, 55°21.648'E (c.25 nm from St. Pierre). **22 December**—Total of 17 individuals came to the chum: two at 16.10–16.58 h [MP#17: photographed, MP#18; both together for first ten minutes, but MP#17 stayed on and off for 48 minutes], one at 17.10–17.15 h [MP#19: photographed], one at 17.20–17.36 h [MP#20], three at 17.52–18.02 h [MP#21–23], one at 18.08–18.18 h [MP#24: photographed]; then an influx from 18.39 h, with three at 18.39–18.44 h [MP#25–27, all visiting briefly then continuing in direction of the island], singles at 18.48 h [MP#28: photographed], 18.50 h [MP#29], 18.55–18.58 h [MP#30: photographed], 19.02–19.06 h [MP#31: photographed], and two at 19.08–19.25 h [MP#32–33]. We discounted five further sightings as possibly the same. All were at 21°42.586'S, 55°21.648'E (c.25 nm from St. Pierre). Summary in Table 2.

Description and at-sea recognition

A full description of Mascarene Petrel follows, based on the 33 birds studied. Our observations confirm that in structure and behaviour *P. aterrima* is a typical *Pseudobulweria*, and given reasonable views can be reliably identified at sea but that it is extremely similar, almost identical, in plumage to Great-winged Petrel *Pterodroma macroptera*.

Size.—We observed Mascarene Petrel directly alongside Barau's Petrels, Wedge-tailed and Tropical Shearwaters (which three species breed on Réunion and are the most frequent offshore), and Bulwer's Petrels, as well as twice with Jouanin's Petrels and once Great-winged Petrel. These observations confirm that Mascarene Petrel is medium-sized



Figures 6–8. Bill structure of Mascarene Petrel *Pseudobulweria aterrima* (left and centre; adults, off Réunion, December 2012) and Great-winged Petrel *Pterodroma macroptera* (right; off Durban, South Africa, November 2013), showing Mascarene’s well-developed latericorn (6a), mandibular unguis (6b), and the large protuberance of the maxillary unguis (6c). Here, extreme variations of the hook tip; on the left lacking, centre maximum, but still shorter and less pointed than in *Pterodroma* (Hadoram Shirihai, © Tubenoses Project)

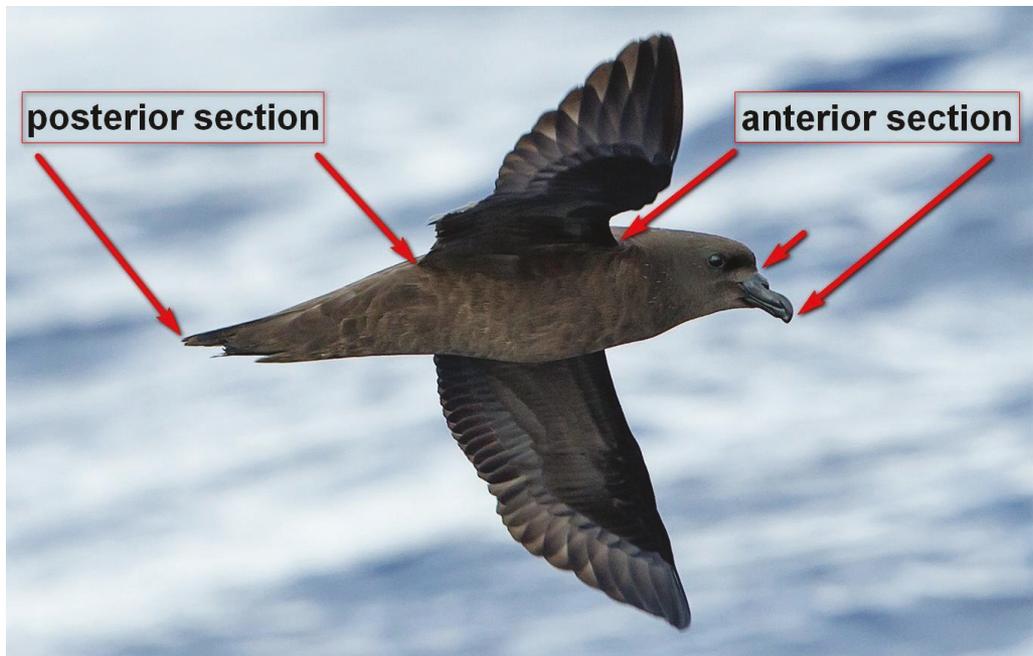


Figure 9. Adult Mascarene Petrel *Pseudobulweria aterrima*, off Réunion, December 2012; diagram describing body structure and proportions—see text (Hadoram Shirihai, © Tubenoses Project)

and somewhat smaller, at least in wingspan, than Barau’s Petrel, Great-winged Petrel and Wedge-tailed Shearwater, by 7–15%, and in overall length is smaller than the first two by 5–10%, and by as much as *c.*20% from the third. However, it is larger and heavier than Tropical Shearwater and Jouanin’s Petrel, by 10–15% in wingspan and 5–10% in overall length. It is much larger than Bulwer’s Petrel, by *c.*20% in wingspan and 15% in length. Total length is *c.*350 mm (Riethmuller *et al.* 2012) and wingspan 880 mm. Perceived size and bulk at sea are corroborated by weights in Table 3 (full measurements appear in Table 1).

Proportions.—Typical *Pseudobulweria* with large bill, well-protruding head and neck, and proportionately long wings, but also a very long posterior section (rear section of body with tail, behind trailing edge of wing; Fig. 9).

Head and bill.—Head in profile rather square, with an almost 90° slope to the forehead, flattish crown, and a noticeable bulge at the apex of the forehead (e.g. Fig. 1). The size and arrangement of the bill plates result in a highly compressed stocky bill, distinctly different from the bill structure of *Pterodroma* (Figs. 6–8). The well-developed latericorn covers 40–50% of the bill volume in profile (in *Pterodroma* 30–40%). Both unguis are well developed, with the maxillary unguis being massive, covering c.30% of the bill in profile, extending from the base of the naricorn and appearing as a huge rounded lump. The hook tip is very short and rounded, lacking the sharp point of most tubenoses. We found the ‘square’, robust bill visible even at distance, and when close the shape and relative size differs from that of Great-winged Petrel (*cf.* Separation from Great-winged Petrel). However, there is some variation and juveniles, probably also immatures, show a slightly slimmer bill, less thickset, with the hook slightly longer and sharper (*cf.* Bare parts).

Wings.—Proportionately narrow, clearly less pointed than Great-winged Petrel, with the ‘hand’ (= primaries) shorter and a more rounded contour to the trailing edge. The ‘arm’ (= secondaries) appears disproportionately narrower and longer, and comprises c.65% of wing breadth (e.g. Figs. 1, 10, 12, 14). Mascarene Petrel has a characteristic narrow wing of relatively even width. The full-stretched wing has the outermost primary (p1) equal to, or falling short of, p3 and perhaps as short as p4, which produces a short rounded ‘hand’. The spread wings in lateral view can appear rounded, but beware a foreshortening effect. When gliding, and the wings become bowed and partially folded, the outermost primary is longest. This deceptive change in wing formula has also been documented for North Atlantic *Pterodroma* (Shirihai et al. 2010).

Body structure.—Unique, noticeably in length of posterior section (e.g. Figs. 9, 10, 12), affording *P. aterrima* a distinctive overall shape in flight and providing a key identification aid. The species’ long posterior section tapers strongly to a very pointed tail; it is at least 50% longer than the head and neck area, and at least 20% longer than the anterior section, i.e. complete neck, head and bill forward of the leading edge of the wing (e.g. Figs. 2, 9, 12). The undertail-coverts almost reach the tail tip; only the tips of the longest rectrices project, further enhancing the elongated posterior section (e.g. Figs. 1, 2, 9, 12).

In profile, the anterior body of Mascarene Petrel comprises a long neck, rather thick at its base, narrowing towards the head, the central body section with a deep and rounded belly, and the posterior body which is well defined, much slimmer, tapers and is perceptibly long, consequently appearing slightly disproportionate (Fig. 9).

The feet were observed on several occasions, prior to landing and when taking off from the water. They do not project beyond the tail, ending far from the tip. The pointed tail is constantly held folded, or partially so, in flight but on landing or take-off it is spread. It is highly graduated and wedge-shaped, not rounded or square-ended as some field guides illustrate (*cf.* Past records of Mascarene Petrel at sea).

Within *Pseudobulweria* Mascarene Petrel is closest in size and proportions to Beck’s but its square head profile, bill structure and long slim rear body are similar to the smaller Fiji Petrel.

Jizz and flight.—All-dark plumage, long rear body, well-projecting neck and head with heavy bill, plus long, slender, almost even-width wings with rounded tips give Mascarene Petrel a characteristic jizz (e.g. Figs. 1, 2, 9, 12). Like other Procellariiformes, flight modes vary markedly with wind speed, direction and behaviour when birds are actively foraging or in transit.

Réunion experiences little wind in November–February, the optimum months to search for Mascarene Petrel offshore; mean wind speed being 18 kph, Beaufort Force 3, gentle breeze (www.wunderground.com, mean over five-year period). During our three days at



Figures 10–13. Adult Mascarene Petrels *Pseudobulweria aterrima*, off Réunion, December 2012: top two images (10, 12) show characteristic shape with well-projecting neck and head, heavy bill, long and slender almost even-width wings with rounded tips, and long posterior body; bottom two (11, 13) show how brown plumage can look almost black in poor light (Hadoram Shirihai, © Tubenoses Project)

sea, we experienced light to fresh winds, Beaufort Force 1–5, i.e. typical conditions. The following describes the usual flight modes of the species off Réunion.

Flight is typical of *Pseudobulweria*: effortless on long wings, sometimes partially bowed, often fully stretched and extended. When gliding into wind the wings are held rather stiff and straight. Not an energetic flyer, wingbeats were neither deep nor fast but supple. In Beaufort Force 4, moderate breeze, flight was deliberate with only a few shallow flaps and some zigzagging advances over a generally straight course. When excited at the chum, more erratic changes of direction were observed, with swift increases in flapping and pouncing glides. In c.35 kph (Beaufort Force 5–6) winds, several birds performed higher arcs, even if characteristically brief; these began as a gradual ascent to c.7 m above the surface, then a moderate or steep descent to quickly return to the ocean. Actions less agile than most *Pterodroma*. Indeed, Mascarene Petrel never performed the graceful, rapid flight with reluctant flapping, or the high, long and steep arcs and dynamic soaring of *Pterodroma*. Seen head-on, or directly from behind, the wings were held slightly below body level forming a shallow arc. We concluded that Mascarene Petrel generally flies rather low, patrolling the surface, and is readily lost to view between waves before suddenly reappearing.

Plumage.—A uniformly dark brown petrel, but at close range and in different lights, contrasting shades between certain feather tracts and subtle coloration patterns evident. The description below details the finest close views and also how the plumage is perceived at distance. Individual variation will be apparent.

In close views, or good photographs, under overcast conditions the head, neck and body show the following contrasting shades: head and neck dark brown, while from about the breast, or level with the wing's leading edge, to the undertail-coverts the body quite abruptly becomes medium brown; there is also a darker patch on the upper flanks, just below the wing. Head and neck are not only darker but more uniformly so, whilst the body from breast downwards is slightly paler and can appear unevenly blotched due to exposed dark feather bases forming diffuse asymmetric barring. In certain lights and angles, some close-up photographs show rusty, even purple-brown, hues (Figs. 1, 15, 20). The degree of such rusty shades and barring can be subtle and varies individually. Furthermore, in photographs, an exceptional pattern of delicate straw-yellow markings on the neck is apparent, tiny spots that become narrow lanceolate shaft-streaks on the lower neck / breast from where they become very faint; the streaks are reminiscent of *Catharacta* skuas although they are fewer, very much smaller and much less noticeable (Figs. 14, 18). Though only visible in very close views, most birds do seem to have them, if varying in number.

The head has a quite well-marked dark loreal mark, from in front of the eye to the side of the forehead, visible in lateral and head-on views, and on some birds further enhanced by pale patches at the base of the forehead-sides. Some also show a rather large dark area around the eye, but it is very ill-defined and paler than the lores, albeit adding to the overall darkness of the head and neck (e.g. Figs. 2, 13, 15).

The upperparts and upperwing lack any distinct pattern being fundamentally concolorous dark brown (Figs. 10, 15). However, in certain lights the lower back, rump to uppertail, lower scapulars / humerals, marginal-coverts, sometimes the exposed secondaries, and perhaps several outer primaries, are darker brown. The bulk of the remaining coverts are slightly paler due to exposed feather bases. No paler carpal bar or any M pattern on the open wings except, at most, a very faint suggestion of this. From above the pale outer webs of the remiges and narrow whitish primary shafts can be visible, especially when the wing is outstretched (Fig. 15).

The underwing is generally dark, with four consistent, clear patterns and contrasting shades, some important for field identification. Firstly, the median and lesser underwing-



Figures 14–15. Adult Mascarene Petrel *Pseudobulweria aterrima*, off Réunion, December 2012; note structure and jizz, darker shades on head and leading and trailing edges to wings, delicate straw-yellow markings on neck, and diffuse asymmetric barring on body (Hadoram Shirihai, © Tubenoses Project)

coverts are almost as dark brown as the head, and are generally darker than the greater coverts and exposed undersides to the remiges, which are more greyish brown. Secondly, a 'marginal' stripe on the fore coverts and carpal area, covering the lesser, inner median and greater primary-coverts, is blackish brown, forming quite a distinctive forewing band. This recalls the pattern on other *Pseudobulweria*, especially Fiji Petrel, but does not project onto the secondary coverts (i.e. there is no ulnar bar) unlike on many gadfly petrels. Thirdly, the tips to the underside of the secondaries are similarly blackish forming a well-defined trailing edge. Fourthly, the five outermost primaries, especially the 2–3 outermost, are also darker brown, forming a rather diffuse dark wingtip. At certain angles this can appear almost black. The darker tracts, described above, form a 'frame' to the underwing (e.g. Figs. 2, 12–14, 16, 18, 22), which is more, or less, pronounced depending on light, angle and distance.

The tail from below just protrudes beyond the undertail-coverts; from above and below, it is dark brown, concolorous with the uppertail-coverts and rump, or perhaps subtly darker, and shows no pattern.

In bright light the brown of the body and upperwing can appear brighter and richer, and if the underwing catches the light the greyer basal remiges and greater coverts appear paler. At certain angles the feathers on the upperparts and upperwing can appear darker,

exaggerating the contrast with the pale outer webs and primary shafts, whilst in direct sunlight the contrast is reduced. In poor light, such as dawn and dusk, the overall brown plumage appears blacker (Figs. 11, 13).

At distance the head and neck usually appear a shade darker than the rest of the body, the underwing looks almost uniformly dark and the complex dark frame to the underwing is invisible, although the relatively darker fore coverts of the underwing and, to a degree, the paler underwing panel is occasionally visible at 300–500 m.

Bare parts.—The bill is essentially black in grounded juveniles, whilst in adults it is more greyish black, or matt black in shade or harsh light. At sea, bills appeared scratched and bleached, a feature known to indicate adults. The bills of adults appear more robust than those of grounded juveniles, though the measured difference in depth is very slight (10.7 mm for adults vs. 10.3 mm for fledglings; Table 1). Conversely, the tip of the maxillary unguis in juveniles is slightly longer and more pointed, but is still valuable in separation from Great-winged Petrel (see below). Irides blackish. Tarsi striking, pale pinkish flesh with a variable pale bluish tinge (= bluish pink) mostly on the webs. Their colour contrasts strongly with that of the body and feet (Fig. 35). The latter are mostly dark brownish black from the outer side of the base of the tarsi over the outer toes. On the middle and inner toes black covers c.70%, with the base of the webs pink; base of middle toe bluish pink and base of inner toe purer blue. The overall coloration of the tarsi and feet is virtually identical to that of Fiji Petrel (Shirihai *et al.* 2009).

Ageing and moult.—All photographs of grounded petrels examined by us were of juveniles. These had fresh plumage, being evenly feathered, with plumage overall plainer and blacker, less brownish than the adults / immatures documented at sea. Adults / immatures showed, to varying degrees, mixed-generation feathers on the body with fresher darker feathers and older paler browner ones, although most remiges and rectrices were of the same generation. Two birds had 2–3 newer inner primaries, which were fresher and darker, and 1–2 outer secondaries, forming moult limits. None of the 33 petrels seen or photographed had moult gaps in the wings or tail. Overall, the remiges and coverts were still rather fresh and we can assume that adults undertake a complete post-breeding moult, presumably sometime in May–October.

Separation from similar species

To reliably identify Mascarene Petrel at sea, or review any photograph considered to be this species, it is necessary to critically assess size, proportions and some of the subtle colour patterns while taking into consideration the effects of light. Previous experience with other species is beneficial, especially the confusion species discussed here. The sea around Réunion, and the Indian Ocean as a whole, supports other all-dark petrels and shearwaters, and we stress that any claimed Mascarene Petrel away from Réunion waters will be difficult to prove unless well photographed. Most confusion taxa described below are illustrated in Pl. 1–2.

Separation from Great-winged Petrel.—Of greatest concern is *Pterodroma (m.) macroptera* to which the following refers, and not the larger Grey-faced Petrel *P. (m.) gouldi*. This Southern Ocean species breeds in the austral winter. In the non-breeding season it occurs mainly at 25–50°S, but does reach further north with records off Réunion. It is most likely to occur in October–February though Attié *et al.* (1997) mentioned records in July–September. Great-winged Petrel is easily misidentified as Mascarene; they have similar all-dark plumage and even the substantial size difference could be misjudged. Mascarene is 15–20% shorter winged (244 mm vs. c.300 mm). Wingspan is c.880 mm in Mascarene and c.970 mm in Great-winged Petrel. Overall length is c.350 mm and c.390 mm, respectively. Body mass



Figures 16–17. Comparison, at distance, between Mascarene Petrel *Pseudobulweria aterrima* (left: off Réunion, December 2012) and Great-winged Petrel *Pterodroma macroptera* (off Crozet Islands, March 2004): note slim outline, length of posterior body and ratio anterior : posterior in Mascarene Petrel, which shows more neck and lacks deep-chested structure of Great-winged; however, on occasion, the species can possess quite similar profiles (Hadoram Shirihai, © Tubenoses Project)



Figures 18–19. Mascarene Petrel *Pseudobulweria aterrima* (left: off Réunion, December 2012) and Great-winged Petrel *Pterodroma macroptera* (off Crozet Islands, March 2004) in gliding flight, showing typical shapes, with Mascarene's even-width, more slender wings and rounder wingtips; note fine straw-yellow spotting / streaking on neck-sides that may be distinctive of Mascarene (Hadoram Shirihai, © Tubenoses Project)

for Mascarene is max. 270 g, whereas Great-winged is usually considerably more than 500 g. Our experience with both species infers that correct evaluation of these size differences, although substantial, is only possible when other species are directly alongside. Extensive previous experience with Great-winged should greatly assist in this process. Mascarene is a less energetic flyer, especially when flying low in light winds, when it can appear heavier and larger than it really is, and conversely Great-winged, being a 'livelier' *Pterodroma*, can in strong winds ostensibly appear smaller and slimmer. Separation is best based on structural differences.

Compared to Great-winged (Figs. 16–23; Pl. 1), the posterior section of Mascarene is longer, more slender, tapering and pointed. Wing shape is narrow and of even width.



Figures 20–21. Comparative close views of Mascarene Petrel *Pseudobulweria aterrima* (left: off Réunion, December 2012) and Great-winged Petrel *Pterodroma macroptera* (off Durban, South Africa, November 2013): on first appearance, practically identical, but note proportions before (anterior section) and after (posterior section) the wing; head shape and bill structure are key features, while the outer primary of this Great-winged is still short and growing (at end of post-nuptial moult) resulting in a rounder wingtip, closer to Mascarene Petrel (Hadoram Shirihai, © Tubenoses Project)



Figures 22–23. Comparative close views when arcing of Mascarene Petrel *Pseudobulweria aterrima* (left: off Réunion, December 2012) and Great-winged Petrel *Pterodroma macroptera* (off Durban, South Africa, November 2013): it is unlikely that observers claiming Mascarene Petrel in the past appreciated the close similarity between the two species (Hadoram Shirihai, © Tubenoses Project)

Great-winged is altogether more stout and thickset with a large rounder head, relatively shorter bull-necked appearance in flight, deep full chest, stockier belly, and broader rear. The latter is due to a shorter projection of the posterior body, which is broad and less tapering. The wing of Great-winged has a longer, more pointed ‘hand’ and a considerably wider ‘arm’. The line of the central body smoothly and gradually becomes the rear, yet in Mascarene there appears to be a noticeable step between the two sections.

Mascarene Petrel is languid in flight, flying relatively low above the water, recalling a shearwater rather than a *Pterodroma* and lacking the dashing aerial manoeuvres of that genus. However, in the non-breeding season, away from Réunion and where storms may occur, the flight could differ. Mascarene displays what we describe crudely as a ‘crucifix’ outline, whereas the overall outline of Great-winged is more ‘anchor-shaped’ with the wings swept back and a squarer tail.

In close views of Mascarene, the more square-shaped head, with its vertical forehead, is very different to the rounder shape of Great-winged and the diagnostic bill structure can be seen; the distal end of the naricorn slopes at 45–50° from the latericorn, less acute than in Great-winged Petrel, and the nasal tubes differ in shape.

Mascarene and Great-winged Petrels have identical plumage; even the delicate patterns and subtly shaded areas appear to overlap. We could not detect any consistent or clear-cut plumage feature that separates them. Mascarene tends to show a better-developed dark ‘frame’ to the underwing, including the ‘forewing band’, but weaker patterning on the upperwing. Many Great-winged in moult, or when fresh, have a bluish-grey cast to the greater and median coverts, which can appear like a distinct upperwing panel, even if ragged; a feature we did not see in Mascarene. However, this is much reduced with wear and only visible in certain light, angles or close views. Many appear as uniformly dark as Mascarene. Head and body plumage is identical except for one feature that might be consistent: Mascarene has faint straw-yellow spots and streaks on the neck, although these vary individually. We studied enlarged photographs of 50+ Great-winged Petrels and none showed this feature, but it requires further checking with birds of different ages and feather wear.

Separation from Wedge-tailed Shearwater.—The dark morph of this shearwater is common off Réunion, and elsewhere in the Indian Ocean, and should prove straightforward to identify if the slender bill is seen. There are two issues to consider. Firstly, the low, lethargic flight of Mascarene Petrel is reminiscent of shearwaters, especially this species. Secondly, they are similar, in that both glide low over the water, moving from low arcing and banking into the wind to slow bursts of wingbeats of short duration. For these reasons, we thought we were being approached by a Wedge-tailed Shearwater only to find it was a Mascarene Petrel and vice versa, but at closer range bill alone identified the species.

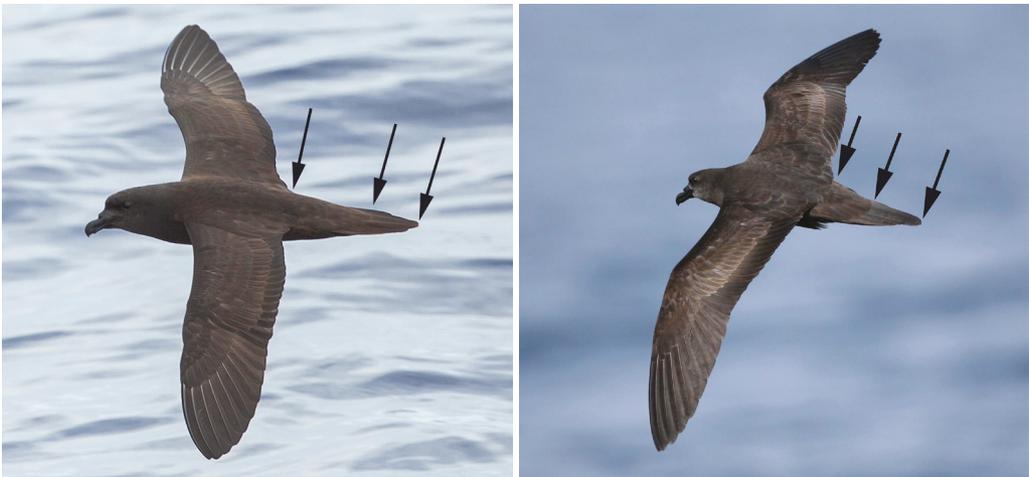


Figures 24–25. Comparison between Mascarene Petrel *Pseudobulweria aterrima* (left) and Wedge-tailed Shearwater *Ardenna pacifica* (right) off Réunion, December 2012, photographed at the same distance; note how they resemble each other in shape and colour, but it is possible to ascertain diagnostic differences in bill, head / neck and tail structures (Hadoram Shirihai, © Tubenoses Project)

We noted that Wedge-tailed Shearwaters off Réunion appeared smaller than in the Pacific. We are unsure if this is geographical variation, or perhaps age-related, but because local Wedge-tailed Shearwaters can appear the same size as Mascarene Petrel, the latter could be overlooked especially among flocks of shearwaters. Confirmation that the approaching bird is a shearwater may require views at 300–500 m and sometimes much closer, 100–200 m, to confirm the bill. Their plumage is rather similar including underwing pattern. The tail of Wedge-tailed is usually longer and the wedge-shaped tip often visible.

Separation from Jouanin's and Bulwer's Petrels.—The two *Bulweria* are dark-plumaged petrels closely related to Mascarene. The larger, Jouanin's, is close in size to Mascarene and can have a quite similar upperwing pattern. Bulwer's Petrel with its smaller size, lighter build, faster and typically fluid flight, and pale upperwing-coverts bar, is usually safely identifiable at sea, but observers need to evaluate size correctly and be aware that, in some lights and certain angles, the upperwing can appear uniform. Bulwer's Petrel breeds on Round Island, off Mauritius, the only known breeding site in the Indian Ocean, and was rather frequently recorded by us, whereas Jouanin's Petrel was uncommon (Table 4). Seasonality of either in Réunion waters is largely unknown. Veit *et al.* (2007) recorded 21 Jouanin's north of Réunion during four days at sea between Mauritius and Mayotte in January 2004. Therefore, any claim of Mascarene Petrel will need to eliminate especially Jouanin's Petrel.

Compared to Mascarene, Jouanin's is smaller and sligher. The leaner silhouette comes from a relatively small head, thin neck, and slim posterior body with proportionately long tail. The square-shaped head with steep forehead and dark lores appear similar, although both species when on the sea can show a rounded crown. When fresh Jouanin's can have uniform upperwings, like Mascarene, though some worn birds have a pale panel on the greater coverts. This feature is highly variable depending on feather wear, and its prominence alters with angle and light. Underwing pattern in both species is similar but Mascarene can show stronger contrast between the brown shading and dark 'frame', whereas the underwing of Jouanin's is more uniform. There may be overlap and the effect of light may render these differences of limited use. We found only two plumage features



Figures 26–27. Comparison between Mascarene Petrel *Pseudobulweria aterrima* (left: off Réunion, December 2012; Hadoram Shirihai, © Tubenoses Project) and Jouanin's Petrel *Bulweria fallax* (off Muscat, Oman, September 2006; © Hanne & Jens Eriksen): some Jouanin's have a characteristic pale upperwing-coverts bar, but note Mascarene's relatively shorter exposed tail-feather projection beyond the longest upperwing-coverts.



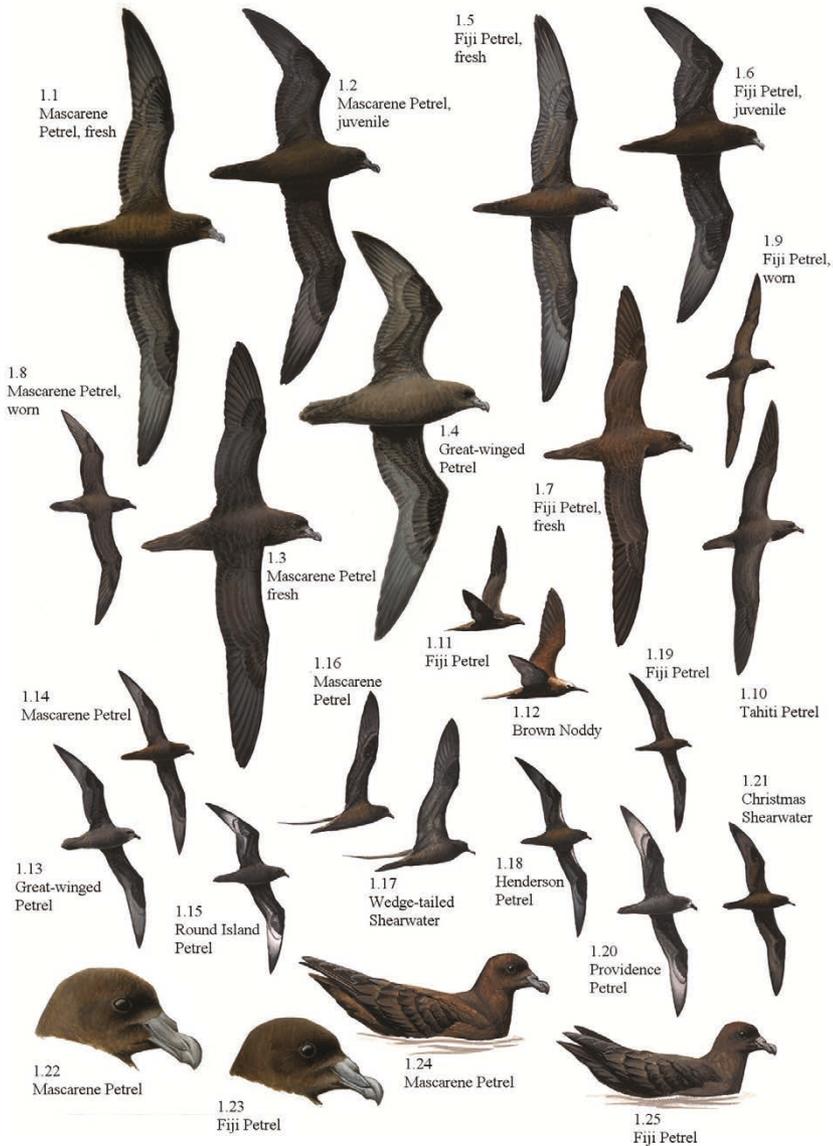
Figures 28–29. Comparison between Mascarene Petrel *Pseudobulweria aterrima* (left: off Réunion, December 2012; Hadoram Shirihai, © Tubenoses Project) and Jouanin's Petrel *Bulweria fallax* (off Hasik, Oman, November 2005; © Hanne & Jens Eriksen): note similar plumage from below, but Jouanin's is smaller, more slender, has a narrow neck, long bill (usually held forwards and downwards) and typically a different flight; several older records of Mascarene Petrel did not eliminate this species.

that could help: 1. Mascarene has unique delicate straw-yellow markings on the neck; and 2. Jouanin's often has some dull greyish to slate-blue hue on the head and / or neck and often the upperparts, especially scapulars. However, these features vary individually, requiring cautious use and close views. Identification of Mascarene and Jouanin's rests therefore on correct evaluation of size and shape, flight mode and behaviour.

Their wing lengths are identical, although they have different wingspans, *c.*880 mm in Mascarene vs. *c.*790 mm in Jouanin's; overall length is longer also, *c.*350 mm vs. *c.*310 mm, whilst body mass is 28% larger for Mascarene at mean 222 g vs. 173 g for Jouanin's (Table 3). The proportionately longer wings of Mascarene are frequently held stiff and the flight is less erratic than Jouanin's, which flies low to the water zigzagging, changing height and altering direction more rapidly with shorter glides and arcs. In calm conditions Jouanin's has graceful flight, consistent and purposeful with deep elastic wingbeats, reminiscent of a small skua, followed by glides. Jouanin's wings may appear more angular, the 'arms' often pointing forwards so the carpal is the most forward point of the wing, the 'hands' swept backwards producing an impression of effortless flight.

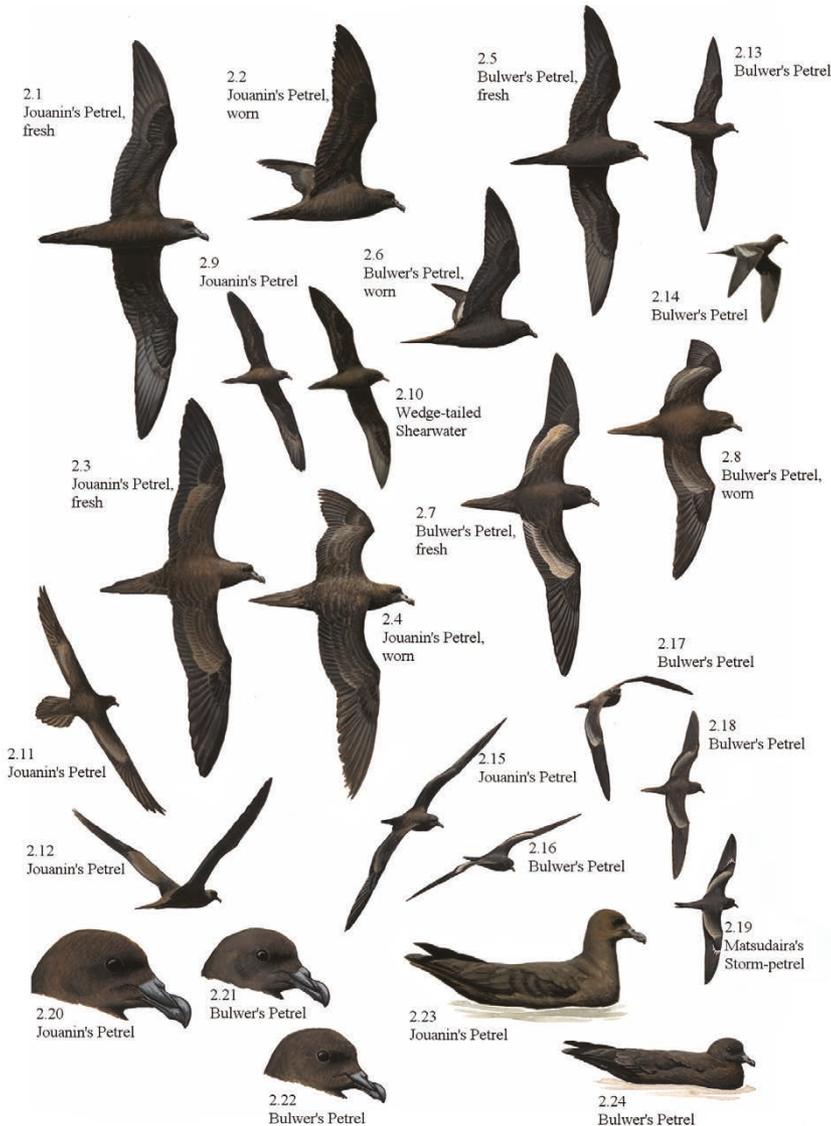
The posterior body of Jouanin's is more streamlined than Mascarene. When Jouanin's is seen with the tail fully folded, the projection of the posterior body is *c.*60% longer than that of the head and neck before the wing, and *c.*30% longer than the anterior section to the bill tip, vs. *c.*50% and *c.*20% respectively in Mascarene (Figs. 26–29). Thus, both have similar proportions, and any differences should be used cautiously in comparing the two species, especially as the tails of *Bulweria* can be shorter due to wear, and the outline of a bird may alter with flight mode and angle.

Jouanin's has a proportionately longer tail than Mascarene. It is graduated with a noticeable 'step' midway along the outer tail. Tail to wing ratio is 98.7% compared to 97.7% in Mascarene. The length of the exposed central rectrices, beyond the uppertail-coverts, is half the total posterior body (from the trailing edge) yet in Mascarene the exposed tail feathers comprise only one-third of the total posterior body (Figs. 26–27). Jouanin's has a



Plates 1–2: Plate 1: Mascarene Petrel *Pseudobulweria aterrima* and other dark, medium–large petrels and shearwaters of the Indian Ocean, plus various Pacific Ocean species that could be confused with Mascarene (and Fiji *Pseudobulweria macgillivrayi*) Petrel. Plate 2: the closely related, all-dark, medium–small Jouanin’s *Bulweria fallax* and Bulwer’s Petrels *B. bulwerii*. Identifying Mascarene from the very similar Great-winged Petrel *Pterodroma macroptera* is the greatest challenge, followed by Jouanin’s Petrel. Dark-morph Wedge-tailed Shearwater *Ardenna pacifica* and ‘Round Island’ Petrel *Pterodroma arminjoniana* (and hybrids) also require eliminating. Mascarene and Fiji Petrels are extremely similar, differing principally in size; both are illustrated, being possible vagrants, for example, to parts of the Pacific; in this region other all-dark tubenoses may occur, so Henderson *Pterodroma atrata* and Providence Petrels *P. solandri*, together with Christmas Shearwater *Puffinus nativitatis*, are included.

Variation between fresh adult **Mascarene Petrel** (1.1, 1.3), worn (1.8) and juvenile (1.2) with its slimmer bill and more uniformly dark plumage; the latter exaggerated in poor light. Corresponding variation shown within **Fiji Petrel** i.e. fresh adult (1.5, 1.7), worn (1.9) and similar/darker juvenile (1.6). Fresh adult **Great-winged Petrel** (1.4) is portrayed, the similarity between the two shown in 1.13 and 1.14. Dark-morph ‘**Round Island**’ Petrel (1.15), here a relatively well-marked bird with clear white primary bases (a rare variation has darker underwings). For size comparison, relevant around Fiji, **Tahiti Petrel** *Pseudobulweria rostrata* is included; its white belly is diagnostic, but is sometimes invisible from above (1.10). At first glance, or distant view, narrow bill of dark-morph **Wedge-tailed Shearwater** (1.17) cannot be seen, and it can be



confused with Mascarene and Fiji Petrels. **Christmas Shearwater** (1.21) is confusable with Fiji Petrel (1.19), e.g. when arcing or gliding. **Brown Noddy** *Anous stolidus* (1.12) could appear superficially similar, if seen briefly in low flight between waves, or at distance (cf. Fiji Petrel 1.11). **Providence Petrel** (1.20) and the poorly known all-dark, slender **Henderson Petrel** (1.18) are shown for comparison; note underwing patterns. The head / bill profiles, and postures on water, of both adult Mascarene (1.22, 1.24) and Fiji Petrels (1.23, 1.25) are illustrated.

Jouanin's Petrel, here showing fresh (2.1, 2.3) and worn (2.2, 2.4) adults, their jizz changing with posture, and corresponding plumages of **Bulwer's Petrel** (2.5–2.8). Dark-morph **Wedge-tailed Shearwater** (2.10) shown here for jizz and size comparisons with Jouanin's Petrel. Different flight modes of Jouanin's and Bulwer's Petrels showing variation and impressions, e.g. particularly large, bulky and dark Bulwer's Petrel (2.8), and when head-on (2.16), compared to an atypical slim Jouanin's Petrel (2.12, 2.15), with a spread tail (2.11) imparting a more rounded shape. Bulwer's Petrel in flight (2.13, 2.14, 2.17) showing typical elastic flight of both *Bulweria*, which compare (2.18) with all-dark **Matsudaira's Storm Petrel** *Oceanodroma matsudairae* (2.19). Head / bill profiles and postures on water of adult Jouanin's (2.20, 2.23) and Bulwer's Petrels (2.21, 2.22, 2.24) also depicted.

Plates by Tim Worfolk, © Tubenoses Project, from *Albatrosses, petrels and shearwaters of the world: a handbook to their taxonomy, identification, ecology and conservation* (Shirihai & Bretagnolle, illustrated by T. Worfolk, in prep., Christopher Helm, London).

proportionately smaller head and more slender neck, with a deep and long bill, often held forwards and downwards. Correct evaluation of bill size and structure, including formation and relative sizes of the plates could prove crucial with any photographic identification.

Potential confusion with other dark-coloured petrels and shearwaters.—The location of Réunion and its relationship to the Subtropical Convergence to the south, where tropical, temperate and much colder waters merge, brings various tubenose species together in varying numbers. These include several dark-coloured petrels and shearwaters that could be confused with Mascarene Petrel: dark-morph Trindade Petrel *Pterodroma arminjoniana* plus hybrids from Round Island, Mauritius (collectively 'Round Island Petrel'), Kermadec *P. neglecta*, Soft-plumaged *P. mollis*, Kerguelen *Lugensa brevirostris*, White-chinned *Procellaria aequinoctialis* and Spectacled Petrels *P. conspicillata*, and Sooty *Ardenna grisea* and Flesh-footed Shearwaters *A. carneipes*. Fortunately, all these possess diagnostic features and are readily identifiable, despite having all-dark or mostly dark plumage.

Genetic analysis has confirmed that Trindade Petrel on Round Island is interbreeding with Kermadec and Herald Petrels *Pterodroma heraldica* (Brown *et al.* 2010) resulting in mixed plumages. Nevertheless, recent studies by HS has shown that all dark-morph individuals retain sufficiently obvious white / pale patches on the underside of the primaries and always lack the all-dark underwings of Mascarene Petrel.

Dark-morph Soft-plumaged Petrel is fully described in Shirihai (2007) and is more common in the Indian Ocean than elsewhere. It is unclear if dark individuals represent a gradual cline in variation, possibly being phases and not morphs, as there is broad variation with extremes looking almost all dark. When fresh these are greyish in ground colour but when worn are more brownish-tinged; even these are easily eliminated vs. Mascarene. They have pale inner underwing-coverts, at least a trace of the species' usual breast-band and upperwing 'M' pattern, a shorter tail, and typical *Pterodroma* shape and flight.

Kerguelen Petrel occurs in subantarctic and Antarctic waters, and is generally all dark. Many guides do not describe its uniqueness well; it is a squat-bodied, large-headed petrel with distinctive long arched wings and a short tail. Flight includes towering above the water surface. When close, it has diagnostic silver-grey flashes to the primaries, greater primary-coverts and lesser and marginal forewing-coverts, especially in strong light (Shirihai 2007). It is very different to Mascarene Petrel.

The two *Procellaria*, White-chinned and Spectacled Petrels, are wholly, or largely, blackish brown but readily separated from Mascarene by their much larger size, different structure and proportions, including shorter tail. Both have a mainly yellowish bill, and Spectacled has distinctive though variable white 'spectacles' (*cf.* Shirihai 2007).

The two *Ardenna* are readily separated by shape and flight, but Flesh-footed Shearwater can adopt a casual direct flight with less flapping, superficially resembling a petrel when distant. It has a distinct pinkish base to the bill. Sooty Shearwater has diagnostic silvery linings / flashes in the underwings. Both have a slim bill, very different to that of Mascarene Petrel. Sooty Shearwater might be considered an unlikely confusion species, yet in Fiji (Shirihai *et al.* 2009) we witnessed experienced observers misidentify it for Fiji Petrel.

Mascarene versus Fiji Petrel.—The extremely similar and very rare Fiji Petrel is known only from the island of Gau. The prospect of it reaching the western Indian Ocean appears highly unlikely, but possible vagrancy of Fiji and Mascarene Petrels to the north-east Indian or south-west Pacific Oceans, e.g. off south-east Australia, cannot be ignored. They are virtually identical in structure and plumage (Pl. 1) but differ markedly in size: Mascarene wingspan 880 mm, total length 350 mm; Fiji Petrel 730 mm and 290 mm, respectively (Shirihai *et al.* 2009). Even the bill, including the plates, is the same, although that of Fiji Petrel is clearly smaller. The variable straw-yellow markings on the neck of Mascarene

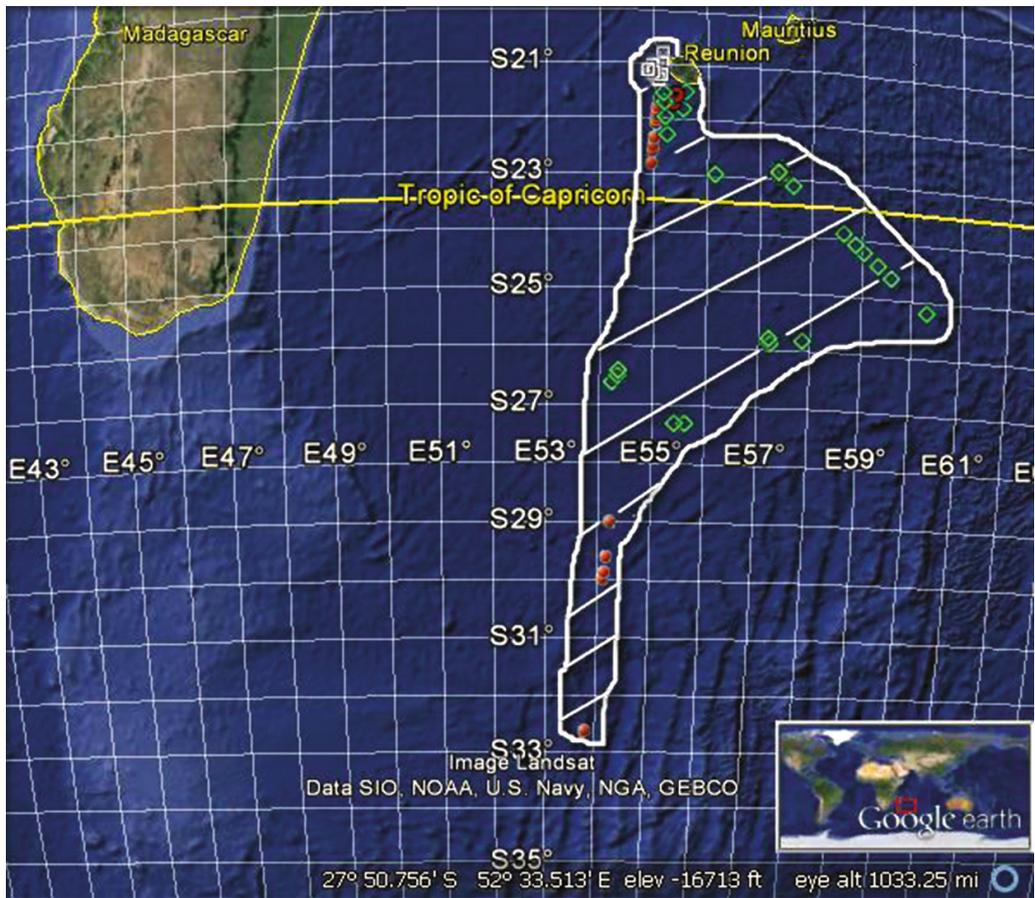


Figure 30. Distribution of Mascarene Petrel *Pseudobulweria aterrima* showing all ‘probable’ and ‘certain’ records at sea, to December 2012 (hatched area), $n = 80$, with records mainly close to Réunion as expected. See Fig. 5 for precise coordinates of our expedition. Note that all records were between south-east and north-west of Réunion and in November–March. Pelagic distribution in non-breeding season unknown. Legend: green open diamonds = records from Attie *et al.* 1997; red-filled circles = records from Hyrenbach (2003); white open squares = records from S. Jaquemet (*in litt.* 2013); and red open circles = this expedition. Satellite images courtesy of Google Inc. All rights reserved © 2013 DigitalGlobe.

appear to be lacking in Fiji Petrel. Vagrants of either species would be extremely difficult to confirm without biometric measurements and / or genetic analysis.

Past records of Mascarene Petrel at sea

Errors in the literature.—The literature has repeatedly described the species wrongly, with inaccurate illustrations of profile, proportions, tail shape, etc. Emphasis has been placed on the wrong features, and erroneous and misleading statements have been perpetuated. Most recently, Safford & Hawkins (2013) stated that ‘head and tail protrude equally either side of wings’ and ‘tail always appears rounded rather than pointed’. Skerrett & Disley (2011) mistakenly described the tail as ‘short’ and ‘squarish’. Onley & Scofield (2007) placed undue emphasis on underwing pattern, describing it incorrectly, i.e. ‘presence of silvery underwing should separate Mascarene from most dark petrels and shearwaters’,

an error that possibly arose from photographs of grounded birds in which camera flash had reflected ('burnt') the paler bases to the underwing-coverts (an illusion reported in Shirihai *et al.* 2009). The plates in all these works illustrate these misconceptions, adding to the perplexity.

Also, with no certain at-sea field descriptions, many authors have assumed the flight of Mascarene to be the same as most *Pterodroma*. For example, Harrison (1987) stated 'probably swift, bounding in high arcs with rather heavy powerful jizz' and Enticott & Tipling (1997) 'probably swift with typical high *Pterodroma* arcs'. The regional field guide (Sinclair & Langrand 1998) stated 'flight action similar to Great-winged Petrel but more agile' so correctly compares it with the principal confusion species, but is difficult to interpret even with knowledge of Great-winged. These descriptions do not convey the build or outline of Mascarene Petrel, or describe the flight, at least in the usual conditions off Réunion. All of these errors, taken together, have led unsurprisingly to uncertainty and misidentifications.

At sea records off Réunion and elsewhere.—Several claimed Mascarene Petrel records have since proven spurious due to lack of knowledge of confusion species, e.g. a specimen from Mumbai recently confirmed as a Jouanin's Petrel (Praveen & Kelvin 2013) and a record from Oman now also known to be of Jouanin's Petrel (*cf.* Jouanin 1970, 1996, Bourne 1996).

Attié *et al.* (1997) listed 28 sightings, involving 31 birds, between 7 November and 29 March, 1978–95, of which ten were ranked 'certain'; all were at latitudes south of Réunion with the furthest 580 km from the island. The other records were classed as 'possible' (four) and 'probable' (17). Jaquemet *et al.* (2004) recorded seven Mascarene Petrels during 36 research cruises from Réunion in February 2001–October 2002; most trips were west of the island, their records of Mascarene were in the sector north-west to south-west. In January 2003 multiple observers undertaking the Southern Indian Ocean Marine Bird and Mammal Survey, aboard a research vessel that departed Réunion for Western Australia, recorded 14 Mascarene Petrels; all were south-southwest of Réunion, the furthest 1320 km from the island (Hyrenbach 2003). It is notable that another scientific cruise, the 38-day Southern Indian Ocean Seamounts that departed Réunion on 12 November 2009, heading south-east then west to South Africa, recorded 36 seabird taxa but no Mascarene Petrels (Rogers *et al.* 2010).

There have been other claims, for example in trip reports by visiting birders and casual sightings reported on the internet. One involved a posting to Birding-Aus (<http://birding-aus.org>) entitled 'Mascarene Petrel, first record for Australia' (<http://bioacoustics.cse.unsw.edu.au/archives/html/birding-aus/2002-12/msg00335.html>), which claimed >45 Mascarene Petrels during a cruise from Mauritius to the islands of the South Indian Ocean, and finishing in Australia, with one bird in Australian territorial waters. It was stated this record would be submitted to the Birds Australia Records Committee, but it was never received. Hansbro (2004) later wrote that 20 seen between Amsterdam Island and Australia were reconsidered to be Great-winged Petrels. He stated that Mascarene Petrels had followed the ship the second day after leaving Mauritius (behaviour not recorded but possible, whereas Great-winged Petrels certainly do approach and will briefly accompany ships). Photographs were apparently taken of Mascarene Petrels but despite many requests, from HS & TP, the only ones we have seen, as separate communication to others and in a printed flyer advertising a birding cruise, show Great-winged Petrels.

We cannot verify the validity of all records above, nor trace any photographs (by all accounts none were taken), though we assume many were Mascarene Petrels, e.g. given that Attié *et al.* (1997) described the flight and jizz correctly, they could critically check accounts and descriptions. From now, we recommend that any record or photograph be reviewed and judged against the criteria presented here.

Mascarene Petrel behaviour at sea off Réunion

Feeding technique.—Mascarene Petrels took no interest in our small boat, birds flying close, within 10 m, to feed on food floating on the water surface. They appeared to locate the chum slick using smell and sight. Approach was focused, with no hesitation, on shallow strong wingbeats, some gliding and slight banking before any change of direction to chum scraps. They appeared more determined than other *Pseudobulweria* but this might have reflected the lack of any larger competitors as Mascarene was usually alone. When landing, wings were held aloft and partially open, remaining so whilst taking food. Take-off involved flapping and the feet running across the water surface before becoming airborne. No calls were heard.

Clearly Mascarene Petrel surface feeds and will scavenge at floating offal, and this behaviour, together with a lack of fear of boats, probably means the species is attracted to bycatch, and is therefore at risk from long-lining and other fishing practices.

Return from pre-laying exodus.—On 22 December 2012 a Mascarene Petrel was photographed at sea with a large egg in the uterus, the protrusion being obvious in the contour of the underbody. The swollen area is just above the cloaca, indicating that it is indeed an egg and not an abnormality or growth (Fig. 36). Petrels are known to have disproportionately huge eggs. We believe this to be the first record of a petrel or any other sea- or landbird to be photographed in flight with an obvious egg inside the body.

This bird was returning from the pre-laying exodus and it is highly likely the egg would have been laid the same night. The unexpectedly large number of Mascarene Petrels recorded on 18 December (14 birds) and 22 December (17) may include, and indicate, an influx of other such individuals.

We were positioned in just one sector of ocean, meaning these numbers may represent a concentration of birds heading towards land from the deep ocean, with numbers increasing closer to land, added to which there was an influx as dusk approached. The two interpretations are either that many more Mascarene Petrels were elsewhere, also heading shorewards or, more probably, that we discovered the principal approach route to the breeding sites.

Range at sea.—All at-sea records, probable or certain, of Mascarene Petrels, have been from south-east clockwise to north-west of Réunion, during November to March inclusive (the breeding season), with the furthest some 1,320 km from the island (Fig. 30). Pelagic range in the non-breeding season is wholly unknown.

Breeding distribution on Réunion

Of the four species of petrels breeding on Réunion it is Mascarene that is elusive. VB began searching for breeding sites in 1987, and continued virtually annually until 2002, in conjunction with a complete breeding survey of Tropical Shearwaters on the island (Bretagnolle *et al.* 2000). Almost all mountains were visited at night and at least once in November–March (austral summer). The first confirmation of a Mascarene Petrel breeding site came when an unidentified call was tape-recorded by C. Attié at l'Entre-Deux in September 1988. Bretagnolle & Attié (1996) wrongly suggested that the call was of an unidentified scops owl, given some similarity to a bird from the Comoros. When VB heard Mascarene Petrel for the first time, on 26 December 1997 at Grand Bassin, he realised their mistake. High-quality tape-recordings were obtained and these confirmed that the bird heard by C. Attié in 1988 was also a Mascarene Petrel. Repeated searches undertaken around Grand Bassin between 1997 and 2002 led eventually to the discovery of nine presumed burrows (i.e. birds calling from the ground) at six separate sites, with one on



Figures 31–35. Adult Mascarene Petrels *Pseudobulweria aterrima*, off Réunion, December 2012, showing feeding behaviour at chum: top image (31) gliding in leisurely flight over the slick, low to the water, to investigate frozen chum block (bottom left). When slowing to land, tail spread briefly and appears rounded; centre-left image (32), patrolling the slick, head-on, wings held slightly lower, forming shallow arc; centre-right image (33), lands on water, swims towards floating food, wings held partially open; bottom-left image (34), hesitancy to examine the food. Only surface food taken, wings always kept open against wind; bottom-right image (35), after feeding, takes off by running on water with wings spread (Hadoram Shirihai, © Tubenoses Project)



Figure 36. Adult female Mascarene Petrel *Pseudobulweria aterrima*, off Réunion, December 2012, with a large egg in the uterus (Hadoram Shirihai, © Tubenoses Project)

27–28 December 1997 having at least four birds calling simultaneously. No burrows were seen, nor searched for, as a decision was taken to avoid climbing on cliffs and ledges that could open pathways for cats or rats. At all times observers stayed strictly to marked paths or riverbeds.

In subsequent years, nocturnal searches were organised by Société d'Études Ornithologiques de la Réunion (SEOR), some years involving as many as 30 people. The most recently published data (Riethmuller *et al.* 2012) show that, in the 2008/09 season, Mascarene Petrels were heard on 17 nights of 34 at one known site, yet during the 2009/10 season the species was heard on just three nights of 55 in the field. The most birds calling simultaneously, at any site over the ten-year period, 2001–10, was three. An online media journal in Réunion (<http://www.clicanoo.re>) reported that SEOR positioned an automatic listening station within the breeding area in 2012 and though operated for >800 hours no calling Mascarene Petrels were recorded. Based on maps in Riethmuller *et al.* (2012), it is presumed that the breeding site described by these authors is one of the six original sites located by VB, although a calling bird in January 2001 was at lower altitude (c.1,150 m, vs. above 1,300 m in Riethmuller *et al.* 2012). Apart from the single at l'Entre-Deux, all known sites where ground-calling birds have been found are in Grand Bassin, within 25 km² and at altitudes of c.500 m to c.1,150 m (most below 900 m). There were additional records of birds calling in flight at several places, all within the same 25 km² area.

Birds calling repeatedly from the ground at night were considered to be males, at the entrance to a burrow, attempting to attract females, which behaviour is observed in other petrels, especially Tahiti Petrel (VB pers. obs.). There is some evidence that these are non-breeders, presumably young birds, searching for a mate with calling continuing for several hours. They could be heard on successive nights at exactly the same sites, but not necessarily in consecutive years, e.g. the site with four calling in 1997 had just two in 1998, and one in 1999 and 2002. Hopefully, these lone birds had found mates and thus call less, as known for other rare species with small numbers like Magenta Petrel *Pterodroma magentae*

(G. Taylor pers. comm.). At the site monitored by Riethmuller *et al.* (2012), steadily less calling was witnessed, which they interpreted as reflecting a declining population, even extinction, but we suggest that any single male had found a partner.

Breeding ecology

Attié *et al.* (1997) summarised breeding phenology and Riethmuller *et al.* (2012) provided additional precision, based on grounded fledglings. Mascarene Petrels return to their colonies in July or August. Riethmuller *et al.* (2012) suggested that copulation occurs during this period, but this is very unlikely as the female would need to store sperm in the oviduct for *c.*3 months. According to Riethmuller *et al.* (2012), egg laying is in October, incubation in October–December, and fledging in March–April. Using the dates of collection of 12 fledglings (assuming this being the day they left the burrow), between 1 March and 4 April, plus one on 27 April, with incubation lasting 48–50 days and chick rearing 73–82 days (based on Warham 1990), egg laying is actually mainly 20 October–20 November, with a single extreme late date on 15 December. Our observation of a female with an egg on 22 December is even later than these dates and the suggested influx of females returning to lay in late December does not match known fledging dates. Tropical petrels in general, and Tahiti Petrel in particular (Villard *et al.* 2006), usually display unsynchronised laying and extended laying periods. We cannot exclude this for Mascarene Petrel since fledglings have been recovered over a two-month period.

Peak calling activity recorded by VB was between 25 December and 30 January. Most vocalising birds would have been non-breeders, which visit the colony most frequently and in largest numbers during the chick-hatching period, as is true in most other petrels (VB pers. obs.). Calling activity started around 20.00 h, on average *c.*1 hour later than that of Tropical Shearwaters.

Population size and conservation

Attié *et al.* (1997) suggested that the world population was *c.*1,000 individuals, and proposed a breeding population of 45–400 pairs, although they suggested that the true total was probably at the lower end of this spectrum. This estimate was published before the first colony was discovered. When VB discovered 9–10 burrows, within the 25 km² area, it was thought that perhaps just 25 breeding pairs survived. That 33 different individuals were seen at two locations at sea in just three days possibly demands a reassessment of estimated numbers. It is implausible that only ten pairs are breeding, more likely the total is in the order of *c.*100 breeding pairs (though an even higher figure is possible), which may further fit with the numbers of Barau's Petrels (>500) and Wedge-tailed Shearwaters (*c.*200) seen at sea (Table 4), given their supposed breeding populations on Réunion (3,000–5,000 pairs and a few hundred pairs, respectively). Obviously Mascarene Petrel must also breed outside the currently identified area of 25 km², or the breeding density is much greater than just ten burrows. Optimistically, our at-sea records suggest there are more Mascarene Petrels than concerted efforts to find breeding sites on Réunion currently reflect. It raises hopes that there are more individuals than thought, and that unknown colonies somewhere on the island have ensured the future of this enigmatic bird, at least for now.

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balance—it too, so easily, could be gone forever. We acknowledge the many efforts made by the Société d'Études Ornithologiques de la Réunion (SEOR) to safeguard this petrel, in particular the established and highly respected community programme to rescue any grounded birds. SEOR is now leading the French National Action Plan for the species, and has started a programme of predator control at known colony sites. We thank those that answered our requests for at-sea photographs of putative Mascarene Petrels. Thanks to David Allan, Niall Perrins and Martin Taylor for organising pelagic trips for HS off Durban, South Africa, in November 2013, especially to study variation in Great-winged Petrels. Grateful thanks to the curators and staff of the following museums for access to, or supplying, specimens: American Museum of Natural History, New York (AMNH), University Museum of Zoology, Cambridge, UK (UMZC), Naturalis, Leiden (RMNH), Musée d'Histoire Naturelle, Saint-Denis (MHNR), Muséum National d'Histoire Naturelle, Paris (MNHN), Australian Museum, Sydney (AMS), Museum of New Zealand Te Papa, Wellington (NMNZ), Natural History Museum, Tring (BMNH) and Fiji Museum, Suva (FM). Special appreciation to Tim Worfolk, artist of the forthcoming *Albatrosses, petrels and shearwaters of the world: a handbook to their taxonomy, identification, ecology and conservation*, who spent nearly two months working with us to accurately illustrate some of these species for the first time. Nigel Redman at Bloomsbury Publishing Plc (Christopher Helm) kindly permitted their use. Trevor Hardaker and Peter Ryan supplied images used to study plumage variation in Great-winged Petrels, and Hanne & Jens Eriksen permitted use of Jouanin's Petrel images. TP thanks Sébastien Jaquemet for supplying further details and records from the research pelagics in 2001 and 2002. Edward Soldaat was always helpful in answering questions on petrel morphology and osteology. Richard Klim kindly accessed a specific reference. VB thanks Carole Attié for her dedicated help over nearly 15 years in searching for breeding sites of Mascarene Petrels on Réunion. François Mougeot and Alexandre Millon aided the field work in 1996 and 2002, respectively. Carole Pym gave much-appreciated assistance with logistics on Réunion during the 2012 expedition, and in the production of this paper, which forms part of ongoing research for the Tubenoses Project. Finally, Michael Brooke and an anonymous referee contributed helpful comments.

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