# CENSUS OF WEDGE-TAILED SHEARWATERS *PUFFINUS PACIFICUS* BREEDING AT D'ARROS ISLAND AND ST JOSEPH ATOLL, SEYCHELLES

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**SUMMARY**

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We conducted a census of Wedge-tailed Shearwaters breeding at D'Arros Island and nearby St Joseph Atoll in the Amirantes Islands, Seychelles, to assess potential changes in population size and provide data for future review of St Joseph Atoll as an Important Bird Area (IBA). After identifying all active colony areas on D'Arros Island and within the atoll, we used a combination of direct counts and area-based estimates to determine breeding population size. We estimated that during the 2009/10 breeding season, 254 (95% CI 234–279) pairs of Wedge-tailed Shearwaters initiated nests on D'Arros Island, and 28 655 (95% CI 22 853–36 302) pairs nested on islands within St Joseph Atoll. The number of breeding pairs at the largest colony was similar to estimates from a census conducted in 2002, and the total breeding population within St Joseph Atoll was determined to be the third largest breeding location in the western Indian Ocean, accounting for 16% of the regional population. The results presented here support the assertion that St Joseph Atoll qualifies as an IBA under several criteria and help to demonstrate that the large numbers of Wedge-tailed Shearwaters breeding in St Joseph Atoll have remained fairly consistent over a seven-year period.

Key words: *Puffinus pacificus*, Wedge-tailed Shearwater, estimated breeding population, Seychelles, western Indian Ocean

## INTRODUCTION

The largest of the tropical shearwaters, the Wedge-tailed Shearwater *Puffinus pacificus* breeds in colonies on oceanic islands and has a loosely seasonal breeding cycle that is more synchronous at higher latitudes (Murphy 1951, Whittow 1997). Although they occasionally nest on the surface, Wedge-tailed Shearwaters typically nest in burrows excavated by both members of the breeding pair (Whittow 1997). Colonies are intermittently attended during nest building and courtship, and both sexes undertake a pre-laying exodus after mating to build up energy stores before the incubation period. A single egg is incubated for approximately 50 days; after hatching, the chick may be brooded for up to a week, and fledging occurs when chicks are 103 to 115 days old (Whittow 1997). These pelagic seabirds forage primarily on fish, especially goatfishes (Mullidae), as well as cephalopods and crustaceans (Harrison *et al.* 1983, Catry *et al.* 2009), through a combination of contact-dipping, surface-feeding and diving (Ashmole & Ashmole 1967, Burger 2001). Feeding often occurs in mixed-species flocks found in association with large predatory fishes that drive prey to the surface (Au & Pitman 1986, Jaquemet *et al.* 2004). Threats to their populations include non-native mammalian predators, human disturbance and habitat degradation, mortality due to artificial lighting and overfishing of predatory fish (USFWS 2005).

Wedge-tailed Shearwaters are widely distributed throughout the tropical Pacific and Indian Oceans and have a global population of over 5 000 000 adults (Brooke 2004). Although their numbers may be declining (Brooke 2004), they are currently listed as a species of least concern by the IUCN because of their extensive range and large population size (BirdLife International 2012). Since this species is strongly associated with tuna (Au & Pitman 1986, Jaquemet *et al.* 2004), monitoring of its population may provide important insight into the effects of changing ocean conditions and declining tuna stocks (Burger & Lawrence 2001, Le Corre & Jaquemet 2005).

We conducted a census of Wedge-tailed Shearwaters breeding at D'Arros Island and nearby St Joseph Atoll in the Amirantes Islands of the Seychelles, which host one of the largest colonies of Wedge-tailed Shearwaters in the western Indian Ocean (Millett & Bristol unpubl. rep.). Our objectives were to census all areas with active breeding and to assess any changes in population size at the main colony on Fouquet Island, where a census was conducted in 2002 (Millett & Bristol unpubl. rep.). Because the previous census indicated that the breeding population size of Wedge-tailed Shearwaters at St Joseph Atoll meets one of the criteria for classification as an Important Bird Area (IBA, BirdLife international 2010a), we sought to undertake a comprehensive atoll-wide assessment to provide sufficient data for future review of IBA status.

## STUDY AREA AND METHODS

D'Arros Island (5°24′S, 53°18′E) and St Joseph Atoll (5°25′S, 53°20′E) are privately owned coralline islands in the Amirantes group

of the Seychelles. D'Arros Island is 170 ha (Stoddart *et al*. 1979), surrounded by fringing reef and inhabited by approximately 30 full-time staff. It is administered as a private retreat and research station; the D'Arros Research Centre supports conservation initiatives at both D'Arros Island and St Joseph Atoll. St Joseph Atoll consists of a number of uninhabited islands and banks, which total approximately 139 ha (Stoddart *et al*. 1979) and flank a central lagoon. We follow the island nomenclature of the DOS map (1979, Fig. 1).

**Colony locations and timing of breeding**

To determine the location of Wedge-tailed Shearwater colony areas, we conducted searches for shearwater burrows throughout D'Arros Island and on all islands within St Joseph Atoll from 8 to 13 September 2009. To assess the timing of breeding, we recorded the number of burrows where contents could be confirmed (adult/pair with egg, adult/pair alone, chick or empty) during burrow searches and census activities during 8–10 September 2009 and 3–15 October 2009. Wedge-tailed Shearwaters have a protracted breeding period at tropical locations; although a few nests were initiated by early September at our study site, this was too early to conduct census activities.

**Census**

We conducted a census of Wedge-tailed Shearwaters at D'Arros Island and at colony areas within St Joseph Atoll during 3–15 October 2009, when most active nests were in the incubation stage (Table 1). We used a combination of direct counts and area-based estimates to calculate total number of breeding pairs. Direct counts were restricted to low-density nesting areas on D'Arros Island

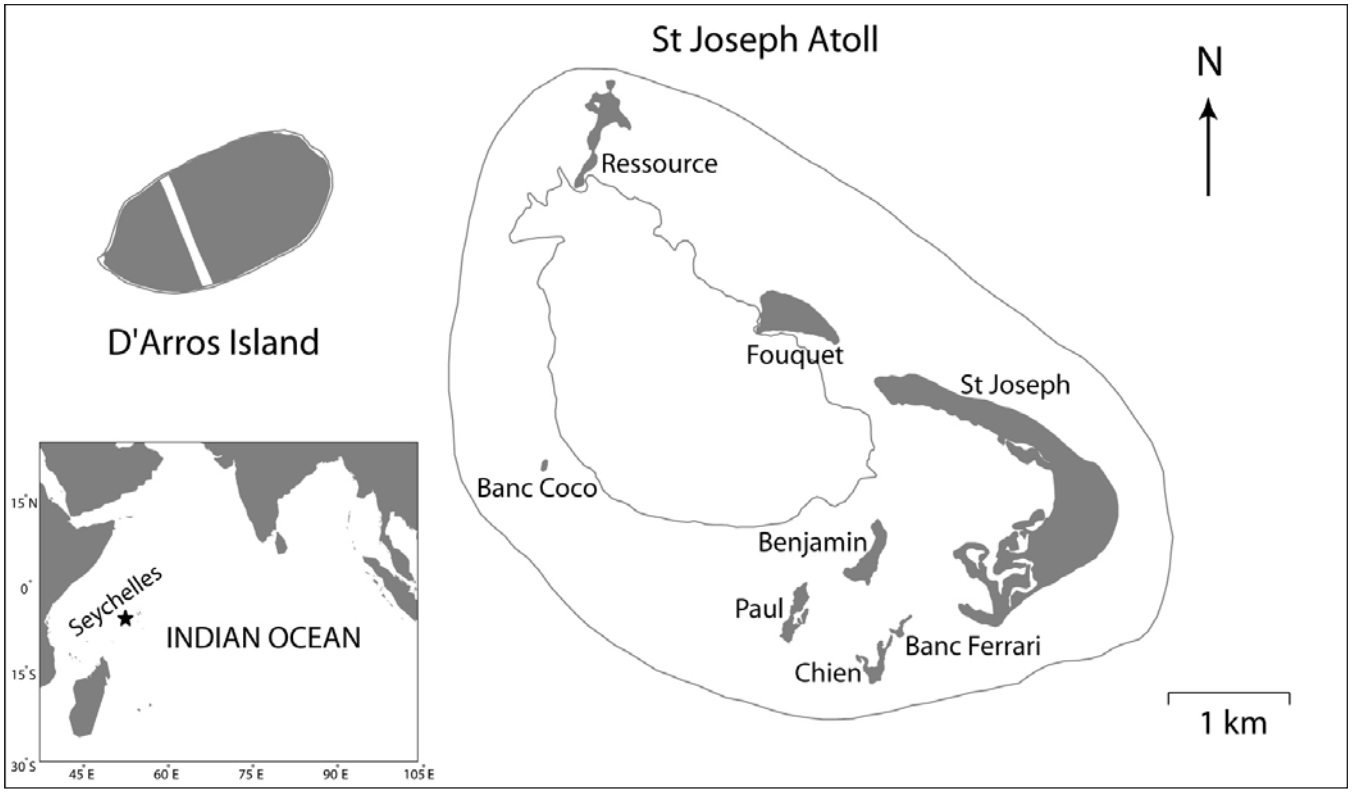


**Fig. 1.** Map of the study area. The location of D'Arros Island and St Joseph Atoll is indicated by the star in the inset map. Solid lines designate beach sand surrounding D'Arros Island and the borders of the sandy reef flat separating the inner lagoon from the outer reef of St Joseph Atoll.

**TABLE 1**
**Status of Wedge-tailed Shearwater burrows with known contents at D'Arros Island and St Joseph Atoll, mid-September and mid-October 2009**

| Location | Date start | Date end | Number (%) of burrows | | | | Total number of burrows |
|---|---|---|---|---|---|---|---|
| | | | Adult/pair with egg | Adult/pair alone | Chick | Empty | |
| D'Arros Island | 10 Sept | 10 Sept | 1 (0.34) | 3 (1.02) | 0 (0) | 289 (98.6) | 293 |
| St Joseph Atoll | 8 Sept | 9 Sept | 10 (1.13) | 75 (8.47) | 1 (0.11) | 799 (90.3) | 885 |
| **Total** | | | 11 (0.93) | 78 (6.62) | 1 (0.08) | 1 088 (92.4) | 1 178 |
| D'Arros Island | 3 Oct | 5 Oct | 13 (22.4) | 5 (8.62) | 0 (0) | 40 (69) | 58 |
| St Joseph Atoll | 5 Oct | 15 Oct | 443 (45.9) | 23 (2.38) | 3 (0.31) | 496 (51.4) | 965 |
| **Total** | | | 456 (44.6) | 28 (2.74) | 3 (0.29) | 536 (52.4) | 1 023 |

(Fig. 2). Area-based estimates were conducted in high-density nesting areas on D'Arros Island and throughout St Joseph Atoll by multiplying the density of breeding pairs in sample plots by the area of the colony.

For area-based estimates, we first created polygons bounding each high-density colony area in Google Earth (Google Inc., Mountain View, CA; Fig. 2 and 3), and calculated the area of each polygon using GE Path (R. Sgrillo, Ilheus, Bahia, Brazil). We then overlaid each polygon with a 15 m × 15 m grid and randomly selected points along the grid at which to place circular sample plots using a custom-built program in Matlab (The MathWorks, Natick, MA). We selected the maximum number of 50 $m^2$ plots that would be possible to sample during the two-week field period; this permitted at least 2.3% of the total area of each colony to be censused (Table 2). It was not possible to use a GPS receiver to locate each sample plot in the field due to extensive coconut palm *Cocos nucifera* cover.

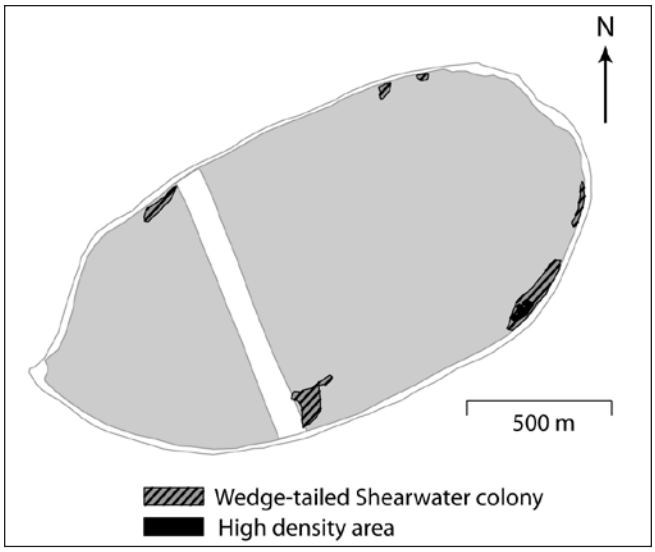


**Fig. 2.** Wedge-tailed Shearwater colony areas on D'Arros Island, 2009. The area in black indicates where plots were conducted for census purposes because of high densities of burrows; otherwise, direct counts were conducted for all other nesting areas on D'Arros Island. The white strip indicates the island's runway.

We therefore calculated the distance to the shore for each sample plot for each cardinal direction. We then selected the shortest route to each plot, located the equivalent latitude or longitude along the shoreline with a GPS receiver and followed a constant compass bearing while pacing the required number of meters to reach the center of the plot. For consistency, the distance was always paced by the same person, without any deviations to avoid thick vegetation, etc., to ensure randomness of plot placement.

Once the plot location was reached, a wooden stake was placed at its center and a rope 3.99 m in length was used to measure the radius of the circular plot, so that the area of each plot was 50 $m^2$. A starting location was marked, and all burrow entrances falling within the circle radius were checked, proceeding in one direction until the arc of the circle was complete. Burrow contents were directly assessed by probing by hand, or in the case of deep burrows, with the use of a stick. Although burrowscopes have been used successfully to determine nest occupancy in shearwaters (Dyer & Hill 1991), we had difficulty maneuvering a scope through burrows at this location because of the presence of plant roots and other obstacles. We therefore relied on searching by hand. As not all burrow contents could be confidently assessed, we used the proportion of "active" nests (incubating adults, chicks or abandoned/broken eggs) to "inactive" nests (empty burrows or burrows with an adult/pair alone) to estimate the number of breeding pairs in burrows with unknown contents. Because it was not always possible to determine whether an adult found in a burrow was incubating an egg (no observations of adults brooding chicks were made during the census), we first calculated the proportion of known incubating adults to known non-incubating adults in order to assign burrows with adults of unknown status to either the "active" or "inactive" category.

On D'Arros Island, estimates of breeding pairs from direct counts were then summed, and the Poisson confidence interval was determined (Table 2). For colony sites in St Joseph Atoll, we used bootstrapping (1 000 resamples per location) to determine the mean density of breeding pairs, standard error and 95% confidence intervals for each location in S-Plus (Insightful Corporation, Seattle, WA). These estimates were then multiplied by the colony area of each site to estimate the number of breeding pairs (Table 2). Bootstrapping was not possible for the high-density area on D'Arros Island because of the small number of plots (n = 3); therefore, to be

**TABLE 2**
**Wedge-tailed Shearwater census results at D'Arros Island and St Joseph Atoll, October 2009**

| | | | | Estimate, mean ± SE | | | |
|---|---|---|---|---|---|---|---|
| | **Colony area (ha)** | **Number of plots** | **% area coverage** | **Nest density (pairs/ha)** | **Burrow density (pairs/ha)** | **Breeding pairs** | **Confidence interval** |
| D'Arros Island – direct counts | 2.75 | | | 47.5 ± 4.2 | 104 ± 6.15 | 131 ± 11.4 | 110–155 |
| D'Arros Island – high density | 0.25 | 3 | 6.05 | 499 ± 45 | 1 000 ± 63.5 | 124 ± 11.1 | 103–148 |
| **D'Arros Island** | 3.00 | 3 | | | | 254 | 234–279 |
| Benjamin Island | 5.12 | 24 | 2.34 | 1 264 ± 202 | 2 492 ± 347 | 6 475 ± 1 037 | 4 739–8 858 |
| Fouquet Island | 15.0 | 71 | 2.37 | 1 365 ± 125 | 2 620 ± 210 | 20 443 ± 1 875 | 17 251–24 366 |
| Ressource Island | 1.46 | 8 | 2.73 | 487 ± 195 | 1 275 ± 520 | 713 ± 286 | 270–1 385 |
| Paul Island | 2.06 | 11 | 2.68 | 498 ± 134 | 1 109 ± 283 | 1 024 ± 276 | 594–1 692 |
| **St Joseph Atoll** | 23.6 | 114 | | | | 28 655 | 22 853–36 302 |
| **Total** | 26.6 | 117 | | | | 28 909 | 23 087–36 580 |

conservative, we calculated the Poisson confidence interval for the estimated number of breeding pairs in this area.

## RESULTS

### Colony locations and timing of breeding

On D'Arros Island, we found six small coastal nesting areas (Fig. 2) of relatively low density. In St Joseph Atoll, extensive high-density colonies were found on Fouquet, Benjamin, Paul and the southern portion of Ressource islands (Fig. 3); in general, burrows were found throughout these areas, wherever small-leafed mangroves *Pemphis acidula* were absent.

We did not find shearwater burrows on St Joseph Island; however, we were able to search only portions of the island because of its size and the density of vegetation throughout most of the island. We searched extensively near the field camp on St Joseph Island, as shearwaters had been seen and heard vocalizing in this area; however, no evidence of shearwater nesting was found. Shearwater vocalizations had also been heard on the northern portion of Ressource Island, but again, no evidence of shearwater nesting was found in this area. Interestingly, in both these areas, high densities of land crabs *Cardisoma carnifex* were observed. Shearwater burrows were not found on Chien Island, Banc Ferrari or Banc Coco.

During mid-September very few active nests were located either on D'Arros Island or within St Joseph Atoll. However, by mid-October 2009, almost half of the burrows with known contents contained incubating adults or pairs, at least within St Joseph Atoll (Table 1).

### Census

Based on our survey, 93.9% of adults found in burrows where contents could be assessed were incubating. After incorporating this estimate, we calculated that 49.9% of all burrows were "active" during the census and applied this proportion to burrows of unknown contents. We therefore estimated that 254 (95% CI 234–279) pairs of Wedge-tailed Shearwaters were breeding on D'Arros Island, and 28 655 (95% CI 22 853–36 302) pairs were breeding within St Joseph Atoll during mid-October 2009 (Table 2).

## DISCUSSION

We used a combination of area-based estimates and direct counts to determine the breeding population size of Wedge-tailed Shearwaters at D'Arros Island and St Joseph Atoll. We assessed samples of burrow contents directly by hand so that breeding status could be determined and applied a correction factor to burrows of unknown contents. We did not use call-playback techniques because of time constraints and the high density and fragility of burrows in the sandy substrate, which made it difficult to access burrows at night without causing damage.

Together with published and unpublished data on Wedge-tailed Shearwater colony sizes in the region, we find that the breeding population size within St Joseph Atoll is the third largest breeding location in the western Indian Ocean, accounting for 16% of the regional population (Table 3). Although the methods for estimating breeding population size at these locations differed between studies, these data represent the best current estimates.

The colony area with the greatest number of Wedge-tailed Shearwater breeding pairs was on Fouquet Island in St Joseph Atoll. Our estimate of 20 443 (95% CI 17 251–24 366) breeding pairs is quite similar to the estimate of 21 286 (95% CI 17 190–25 382) pairs assessed by Millett and Bristol in 2002 (unpubl. rep.). This suggests that the population size of Wedge-tailed Shearwaters has remained relatively constant within St Joseph Atoll during this time. We found greater numbers of Wedge-tailed Shearwaters nesting at Benjamin Island (6 475 pairs; 95% CI 4 739–8 858) and Ressource Island (713 pairs; 95% CI 270–1 385) than previously thought. No census had been conducted at these islands; however, Millett and Bristol (unpub. rep.) projected that *ca* 1 000–2 000 pairs nested at Benjamin Island, and noted that only a very few burrows were present at Ressource Island. In contrast, our estimate of breeding pairs at Paul Island (1 024 pairs; 95% CI 594–1 692) was very similar to Millett and Bristol's approximation that in excess of 1 000 pairs was likely breeding at Paul Island (unpubl. rep.).

Shearwater burrow densities differed considerably among colony areas (Table 2), but were generally similar or lower than densities reported at other breeding locations in the Seychelles (2 488 pairs/ha, Burger & Lawrence 2001), Australia (500–2 000 pairs/ha, Hill *et al.* 1996) and Hawaii (2 800 pairs/ha, Shallenberger 1973). On D'Arros Island in particular, most breeding areas had very low burrow densities (Table 2). In addition, we observed that about half of all burrows were active nests (Table 2), a similar proportion to other published studies (Hill *et al.* 1996, Burger & Lawrence 2001). It is therefore likely that the population size of Wedge-tailed Shearwaters breeding at St Joseph Atoll and D'Arros Island is not limited by nesting habitat, given that neither the proportion of active nests to available burrows, nor overall nesting densities were comparatively high. The presence of apparently suitable, unoccupied nesting habitat, both on D'Arros Island and within St Joseph Atoll, has similar implications. It is interesting to note that we did not observe shearwaters nesting in two areas where high densities of *Cardisoma* land crabs were observed, in the northern portions of Ressource and St Joseph islands, although individuals were seen and heard vocalizing there. We witnessed one instance where a land crab displaced a shearwater from a burrow on Fouquet Island, but we were not able to confirm the breeding

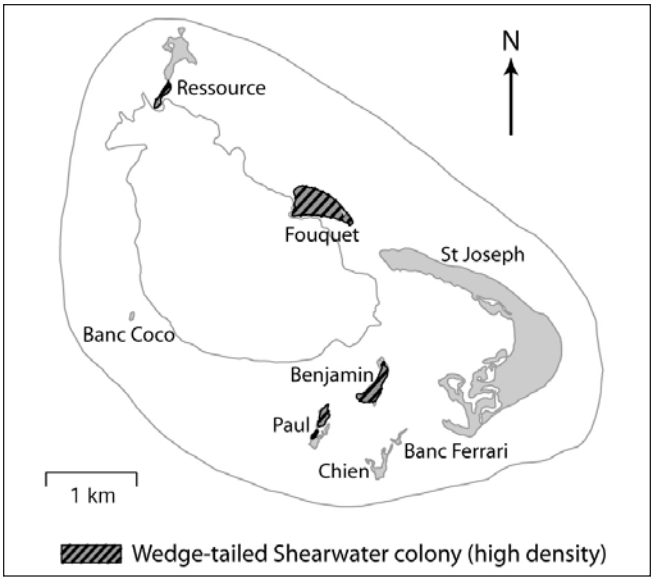


**Fig. 3.** Wedge-tailed Shearwater colony areas within St Joseph Atoll, 2009. All colony areas had high densities of shearwater burrows and necessitated area-based estimates for census purposes.

status of the bird. High densities of *Cardisoma* land crabs may affect suitability of Wedge-tailed Shearwater nesting habitat within St Joseph Atoll. Given the rat-free status of St Joseph Atoll (Millett & Bristol unpubl. rep., Skerrett & Rocamora 2007) and generally low depredation of shearwater eggs (Millett & Bristol unpubl. rep.), land predators are unlikely to affect the breeding success of shearwaters within the atoll. Norway rats *Rattus norvegicus* and feral cats were present on D'Arros Island as late as 2002 (Millett & Bristol unpubl. rep.), but following a successful eradication program in 2003, these mammalian predators are no longer threats to Wedge-tailed Shearwaters breeding there.

Although St Joseph Atoll is currently on a "shadow list" of potential IBAs (Rocamora & Skerrett 2001), insufficient data on the numbers of seabirds and waterbirds that use the atoll have prevented an assessment of IBA status. D'Arros Island is classified as an IBA because of the presence of the range-restricted Seychelles Fody *Foudia sechellarum*, which is listed as near-threatened by the IUCN (BirdLife International 2010b). Our study supports the idea that St Joseph Atoll also qualifies as an IBA, under categories A4iii (more than 10 000 pairs of seabirds) and A4ii (more than 15 000 pairs of Wedge-tailed Shearwaters, or 1% of the global population). Skerrett & Rocamora (2007) and Monticelli *et al.* (2008) demonstrated that St Joseph Atoll qualifies as an IBA under category A4i (more than 1% of the biogeographic population of Roseate Terns *Sterna dougallii* and Black-naped Terns *Sterna sumatrana*) and have therefore advocated for its consideration as a candidate IBA or for an extension of the boundaries of the D'Arros Island IBA to encompass the atoll. Our results reinforce these recommendations, as our breeding population estimates support St Joseph Atoll as an IBA based on criteria relating to congregations of seabird species.

Our results suggest that the number of Wedge-tailed Shearwaters breeding in St Joseph Atoll has remained fairly consistent between the first census in 2002 (Millett & Bristol unpubl. rep.) and our census in 2009; however, additional surveys at regular intervals will be necessary to determine long-term trends. Although Wedge-tailed Shearwaters are not a species of immediate conservation concern (BirdLife International 2012), monitoring of their populations could provide important information on how declining tuna stocks may lead to cascading effects on marine ecosystems in the western Indian Ocean. In fact, the at-sea distribution of Wedge-tailed Shearwaters

**TABLE 3**
**Identified Wedge-tailed Shearwater colonies in the western Indian Ocean**

| Country | Location | Number of breeding pairs | % of population in western Indian Ocean | Reference |
|---|---|---|---|---|
| Mauritius | Round Island | 60 000 | 33.9 | (MWF&NPCSM 2008) |
| Seychelles | Cousine Island | 31 000 | 17.5 | Rocamora & Skerret (2001) |
| Seychelles | St Joseph Atoll | 28 655 | 16.2 | Current study |
| Seychelles | Aride Island | 19 500 | 11.0 | Bowler *et al.* (2002) |
| Seychelles | Cousin Island | 13 000 | 7.3 | Burger & Lawrence (2001) |
| Seychelles | Desnoeufs Islands | 10 000 | 5.6 | R. Bristol, Nature Seychelles, pers. comm. |
| Mauritius | Gunner's Quoin | 4 000 | 2.3 | (MWF&NPCSM 2008) |
| Mauritius | Pigeon Rock | 4 000 | 2.3 | (MWF&NPCSM 2008) |
| BIOT[a] | Chagos Archipelago | 2 863 | 1.6 | McGowan *et al.* (2008) |
| Seychelles | Récif Island | 1 800 | 1.0 | R. Bristol, Nature Seychelles, pers. comm. |
| France | Réunion Island (mainland) | 900 | 0.5 | MLC, unpubl. data |
| Seychelles | Boudeuse Cay | 500 | 0.3 | R. Bristol, Nature Seychelles, pers. comm. |
| Mauritius | Gabriel Island | 325 | 0.2 | (MWF&NPCSM 2008) |
| Seychelles | D'Arros Island | 254 | 0.1 | Current study |
| Madagascar | Islets off Morombé | 125 | 0.1 | Appert (1965) |
| France | Réunion Island (Petite Île) | 65 | 0.04 | MLC, unpubl. data |
| Seychelles | Bird Island | 50 | 0.03 | R. Bristol, Nature Seychelles, pers. comm. |
| Mauritius | Flat Island | 15 | 0.01 | (MWF&NPCSM 2008) |
| Mauritius | Serpent Island | 7 | 0.004 | (MWF&NPCSM 2008) |
| Mauritius | Rodrigues Islets | ?[b] | - | A.S. Cheke, unpubl. rep. |
| Mauritius | Saint Brandon Islands | ?[b] | - | Newton (1958) |
| **Total** | | 177 059 | | |

[a] British Indian Ocean Territory
[b] No estimate of breeding population size included in record

and other seabirds has been proposed as a means of identifying pelagic marine protected areas aimed at benefiting overfished tuna stocks and dependent predators in the region (Le Corre *et al.* 2012). Continued monitoring of the Wedge-tailed Shearwater population at St Joseph Atoll and other locations could therefore help inform whether changes in tuna stocks can be linked to population-level effects on associated seabirds (Le Corre & Jaquemet 2005).

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