



Gadfly petrels of the *Pterodroma feae*-complex in southwestern Atlantic Ocean, Brazil

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Abstract

The *Pterodroma feae* complex comprises three cryptically looking gadfly petrels (Cape Verde *Pterodroma feae*, Desertas *Pterodroma deserta*, and Zino's *Pterodroma madeira*), once regarded as a single species, the Fea's Petrel, *P. feae*. Recent research using geolocators to track and understand their movements away from breeding grounds demonstrated that both Zino's and Desertas Petrels do undergo some long-distance movements. They perform a trans-equatorial migration to remote, previously unknown, wintering grounds, in Brazilian waters off the northeast and southern coast of Brazil during their non-breeding season. However, despite several decades of systematic and intensive beached seabird projects along extensive stretches of the Brazilian coast in these two regions, no specimens of either of these gadfly petrels have been reported. Here, we document two photographic specimen records of gadfly petrels off the Brazilian coast, provide comparative criteria for at sea identification and discuss difficulties to determine species level. First, a heavy-billed male Desertas Petrel was photographed over the continental shelf off the Rio Grande do Sul, southern Brazil, and a second specimen off Espírito Santo, southeastern Brazil, over the Vitoria Seamount, either a Desertas or a Cape Verde Petrel. Apart from Brazilian records based solely on geolocator tracking results, these seem to be the first documented specimen records for Brazil of any species within the *feae*-group, as well as for the southwestern Atlantic Ocean. Further, these records confirm that Brazilian offshore waters are important non-breeding feeding grounds for the *feae*-group.

Keywords At sea record · Distribution · Identification · Occurrence · *Pterodroma deserta*

The *Pterodroma feae*-complex comprises a group of three sister taxa of cryptic gadfly petrels that breed in the Macaronesian Islands, North Atlantic Ocean (Gangloff et al. 2013). Taxonomically, the group was previously defined as a single species (*Pterodroma feae*) but following phylogenetic studies (Zino et al. 2008; Jesus et al. 2009) combined with different breeding data (Ramos et al. 2016) plus distinct morphological and vocal differences (Bretagnolle 1995) confirmed

splitting the complex into three taxa: Zino's Petrel (*Pterodroma madeira*), Cape Verde Petrel (*Pterodroma feae*), and Desertas Petrel (*Pterodroma deserta*). Volcanic islands of mid-Atlantic Ridge are propitious for tubenoses radiation, which is favored by the philopatry (a strong loyalty to their birthplace on remote oceanic islands) observed in the group (Gangloff et al. 2013). These three gadfly species are globally threatened, with small, estimated populations: *P. madeira* with only 160 mature individuals (BirdLife International 2018a); *P. deserta*, 250 to 999 individuals (BirdLife International 2018b); and *P. feae*, 1000 to 2000 individuals (BirdLife International 2018c). The two species with the smallest populations have more restricted breeding sites, *P. madeira* breeding on Madeira Island; *P. deserta*, only on Bugio Island in the Desertas Archipelago; while *P. feae*, with a larger population, reproduces on different islands in Cape Verde Archipelago (Ramos et al. 2016, 2017).

Geolocator studies have confirmed that these three gadfly petrels each showed distinctly annual dispersal patterns

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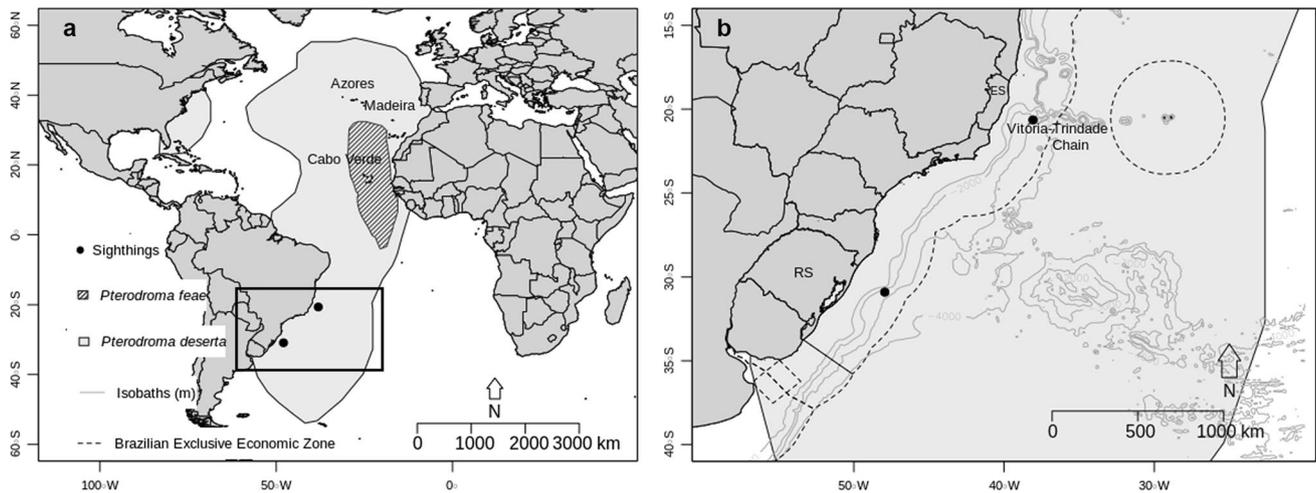


Fig. 1 At sea distribution and records of *Pterodroma feae* lato sensu and *P. deserta* in Brazilian waters presented in this study (by dots). The states where the records were obtained, Espírito Santo (ES) and Rio Grande do Sul (RS) are shown in **a** and **b**. Approximations of the two species distributions are represented as shaded in light grey and the smaller hatched area, based on specific kernel density distribu-

tions (Ramos et al. 2016) in **a**. Specifically, we used the sum of 95% contour lines of breeding and non-breeding periods for each species. (Map redrawn after authorization by R. Ramos, in litt.). In **b** is shown the bathymetric contour and the 200 nautical miles of the Exclusive Economic Zone

(Ramos et al. 2016, 2017). During the breeding season, all three species tend not to forage too far from the colonies, around 500 to 700 km (Ramos et al. 2016), but some *P. deserta* were found to perform huge circular foraging trips (up to 12,000 km) during the breeding season, from waters around Madeira to waters off Newfoundland, Canada (Ventura et al. 2020). During the non-breeding season, it was found that *P. feae* exhibits more restricted movements, staying closer to the breeding areas, in comparison to both *P. deserta* and *P. madeira*. These latter species were confirmed to be long-distance trans-equatorial migrants (Ramos et al. 2016), reaching Brazilian waters, the equatorial coast, and sub-tropical waters in the west portion of the Atlantic Ocean (Ramos et al. 2016, 2017). In general, *P. madeira* was mostly encountered in offshore waters of northeast Brazil, while *P. deserta* occupy southern, eastern, and northeastern Brazilian offshore waters (Ramos et al. 2016, 2017). Besides the distinctly different patterns of non-breeding distribution between these two groups (Zino's and Desertas vs. Cape Verde Petrels), they also show distinct breeding phenology. Cape Verde Petrel breeds during the Boreal winter, departing from the colonies in late April (Militão et al. 2017), while *P. feae* and *P. deserta* breed during the Boreal summer and leave the colonies during the Boreal autumn (Snow and Perrins 1998; Oliveira et al. 2007).

Based on published tracking information (Ramos et al. 2016), the Brazilian Ornithological Records Committee (CBRO) placed *P. madeira* and *P. deserta* in the secondary list (Piacentini et al. 2015), a category that includes birds without any documentation, such as museum specimens,

photographs, sound recordings (sensu Carlos et al. 2010), but instead published evidence (e.g., tracking by GPS devices or geolocators). The updated CBRO list (Pacheco et al. 2021) changed criteria, accepting tracking data as definitive evidence of occurrence, and thus included the species in the primary list. We hereby present some photographic records of *feae*-complex petrels offshore within the Brazilian Exclusive Economic Zone (Fig. 1) and discuss the at sea identification of the group.



Fig. 2 Desertas Petrel *Pterodroma deserta* off Rio Grande do Sul, southern Brazil, 22 April 2018, demonstrating the contrasting pattern of light gray tapered tail and darker gray mantle, a dark orbital black eye patch, white lores, a robust “meat-clever” stout bill and a heavy built jizz, barrel chest confirming a typical Desertas Petrel and most probably a male

The specimen of *P. deserta* was photographed by FLVN (Fig. 2) off the continental shelf in southern Brazilian waters, 2644-m depth on 22 April 2018, at 14:31 h, 264 km from the coast (30°54'8.00"S; 47°56'26.12"W) Rio Grande do Sul. These images were taken during a scientific voyage, onboard the R/V Alpha Crucis (IO-USP), while researching deep ocean currents and displayed in WikiAves (Vicentini 2018), a Brazilian citizen science ornithological platform for bird photos and sound recordings. FLVN initially identified it as a Soft-plumaged Petrel (*Pterodroma mollis*), before initially AW followed by LB proposed that it was a *P. deserta*.

The encounter of the other *feae*-complex *Pterodroma* (Fig. 3) occurred on 22 May 2019 at 07:21 h, by GMB, KBA, and MR, 226 km off southeastern Brazilian coast (20°38'35.59"S; 38°4'23.91"W). The bird was detected during an expedition aiming to capture for sampling Atlantic Yellow-nosed Albatross *Thalassarche chlororhynchos*. The record was in shall waters, 42-m depth, of the Vitoria Seamount at Vitoria-Trindade Chain. The petrel was attracted by chumming, approaching to within 15 m, flying around the boat for about 5 min, along with two Great Shearwaters (*Ardenna gravis*), and one each of Wilson's Storm-Petrel (*Oceanites oceanicus*) and Black-bellied Storm-Petrel (*Fregetta tropica*).

Both specimens (Figs. 2 and 3) clearly exhibit the combination of light gray on upper tail coverts and tail contrasting with a darker gray back and absence of a gray neck collar, characteristics that separate them from *P. mollis*. The dark orbital area and white lore clearly point them to a *feae*-complex petrel (Flood and Fisher 2013; Howell and Zufelt 2019).

Because the at sea identification of this group is difficult, we based our identification on Shirihai et al. (2010) and Flood and Fisher (2013), in addition to comments by Shirihai (pers. comm). We present our identification steps in the next paragraphs, and a summary of the characteristics in Table 1.

Following Shirihai et al. (2010), *P. madeira* shows the impression of being slimmer than *P. feae* and *P. deserta*, with a small bill relative to its size and different underwing pattern. Whereas, *P. deserta* shows a robust jizz, big head, and deep heavy bill, while the *P. feae* is between *P. deserta* and *P. madeira*. However, there is an overlap between *feae* and *deserta*, with some individuals indistinguishable at sea, except by presumption based on location or wing molt timing (Shirihai et al. 2010). Clearly, both birds (Figs. 2 and 3) are neither as streamlined nor small billed as Zino's, which indicates to *P. feae* or *P. deserta*.

The heavily built appearance is easily defined in our bird recorded in southern Brazil (Fig. 2), as it has a distinctly thick bill and robust body, which confirmed it is a *P. deserta* (Shirihai, pers. comm.). The features of our second bird place it in-between sizes of *P. deserta* and *P. feae*, not as small as a *P. madeira* (Shirihai, pers. comm.). Therefore, we confirm that it is impossible to precisely determine the species and only can place it within the *feae*-complex, either a *P. deserta* or *P. feae*. According to Shirihai et al. (2010), another way to resolve this question is by assessing the bill and wing dimensions and its ratios, information unavailable from pictures.

Another tool that helps in the identification of the group is the color of underwing coverts. Shirihai et al. (2010) scored

Fig. 3 Photos of *Pterodroma* sp. sighted off Espírito Santo, southeastern Brazil, 22 May 2019. The specimen shows a dark gray back contrasting with light gray tapered tail and upper tail coverts, dark orbital area, absence of breast band, confirming a *Pterodroma feae*-complex petrel (a, c, d). The specimen shows an intermediate size of wings and bill robustness between Cape Verde Petrel *P. feae* and Desertas Petrel *P. deserta* (b, c), smudging in flank (c), and some barring in the inner forewing not totally white as in Zino's Petrel *P. madeira*. We note however that Zino's underwing pattern can vary individually

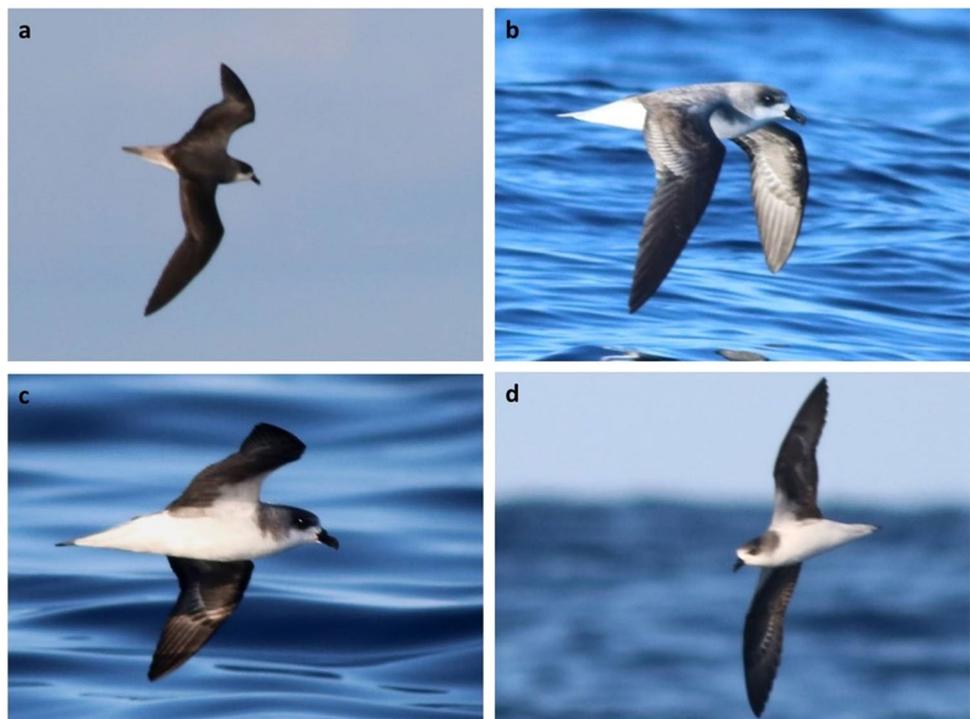


Table 1 Summary of criteria used to identify the petrels showed in photos, based on Shirihai et al. (2010), Flood and Fisher (2013). We present a short description of the main, objective, criteria for Fea's Petrel diagnosis. In the table, each species received a letter (Zino's

Petrel *Pterodroma madeira*: M; Cape Verde Petrel *Pterodroma feae*: F; Desertas Petrel *Pterodroma deserta*: D). The two last columns represent the first record, Desertas Petrel (bird 1), and the second record, *Pterodroma* sp. (bird 2). NA, not applicable

Main criteria to at sea ID	Zino's (M)	Cape Verde (F)	Desertas (D)	Bird 1	Bird 2
Jizz	Medium- to small-sized <i>Pterodroma</i>	Medium-sized <i>Pterodroma</i>	Medium-sized <i>Pterodroma</i> (with some males showing a stronger appearance)	D	F/D
Wingspan	Looks relatively shorter-winged	Looks long-winged	Looks long-winged	F/D	F/D
Score of white amount on primary underwings (0 to 4)*	[0] 13; [1] 20; [2] 25; [3] 27; [4] 15	[0] 85; [1] 10; [2] 4; [3] 1; [4] 0	[0] 25; [1] 46; [2] 24; [3] 5; [4] 0	NA	[2]
Score of white amount on secondary underwings (0 to 4)*	[0] 25; [1] 24; [2] 24; [3] 15; [4] 12	[0] 81; [1] 16; [2] 3; [3] 0; [4] 0	[0] 65; [1] 30; [2] 4; [3] 1; [4] 0	NA	[1]
Primary moult timing	August–December	March–August	October–April	M/F	M/D
Bill size and structure	Slight-billed	Robust	Robust (with some heavy-billed)	D	F/D
Barring in the inner forewing patches on the underwings	Little barring, giving this area a clean-white look	On average shows the strongest barring, with about 65% showing some or strong barring	50% of Desertas Petrel with some barring	NA	M/D
Dark smudging on flanks	Well developed	Poorly developed	Less developed	NA	D

*In brackets the score and outside the percentage of birds found with this score (Flood and Fisher 2013)

birds from 0 to 4, based on the amount of white in primary and secondary underwing coverts. Based on that *P. deserta* and *P. feae* show a darker pattern than *P. madeira*, but, again, there is an overlap of this characteristic in the group. For the first specimen, we could not access this information, while the second shows a score 2 in primary, and score 1 in secondary feathers (Fig. 3b–d). These scores tend more towards *P. deserta* than *P. feae*, but the information was not enough for definitive species-level identification.

Based on extensive field observation of some individuals of the three species in their breeding colonies, Shirihai et al. (2010) point two other supporting criteria toward identification of *feae*-complex petrels. However, the criteria are not diagnostics, because there is overlap among them. The first is the difference in the flank smudging between the three taxa, with *P. madeira* showing this characteristic more developed than the other two species; *P. deserta*, the less; and *P. feae*, intermediate. Figure 3c and d has evidence of the lack of barred or smudging flank, more common in *P. deserta*. The other feature refers to barring in the inner forewing patches on the underwings, *P. madeira* with little or any barring; *P. feae* with the strongest barring pattern, with about 65% of the population showing some or strong barring; and *P. deserta* with 50% of the individuals with this part barred. The second individual (Fig. 3c and d) shows little or no barring in the inner forewing, which is more common in *P. deserta* and *P. madeira*. The features described are in Table 1.

The criteria proposed by Shirihai et al. (2010), allied with the information of the *P. feae* movements in Ramos et al. (2016; Fig. 3), which does not include Brazilian waters, suggest that the second bird (Fig. 3) is more probably a Desertas Petrel. However, we suggest that Brazilian waters could also be a wintering destination for *P. feae*, as already demonstrated by the Cape Verde Shearwater *Calonectris edwardsii* (Petry et al. 2000) which is documented mostly off the southern coast of Brazil, Rio Grande do Sul, but also with northward records along the Brazilian coast.

Both areas where these gadfly petrels were recorded consist of pronounced oceanic slopes (10° and 14° in south and southeastern, respectively) conditions that favor upwelling systems. At the Vitoria Seamount, the sea bottom could contribute to eddies and upwelling processes, which increases marine productivity (Gaeta et al. 1999; Andrade et al. 2004). The association of *feae*-complex petrels and upwelling systems in Brazil had previously been predicted by Ramos et al. (2016). The kernel's distribution probability showed for *P. deserta* overlapped with waters under Cabo Frio upwelling influence (Ramos et al. 2016), a system that also make the southeastern Brazilian waters productive (Valentin 2001).

It is noticeable that, despite being a regular visitor off the Brazilian coast (Ramos et al. 2016), the *feae*-complex birds had remained undetected for such a long time. In fact, there is a previous record of an alleged *P. feae* on ebird database, off Rio de Janeiro stated on 01 April 2016 (by S. Imberti, <https://ebird.org/checklist/S28702550>), where five photos

and a detailed description are provided. Our analysis of the images agrees with the exclusion of Soft-plumaged Petrel and points to the same classification of our second record, a *feae*-complex bird.

The lack of systematic bird surveys off the Brazilian coast, as demonstrated by Mott and Clarke (2018), with undersampled areas, e.g., in the north at the mouth of the Amazon River (Daudt et al. 2019), explains partially the absence of previous *feae*-complex records. Another factor is that in Brazil the main sources of seabird information are based on dead or debilitated specimens on the beaches (Lees et al. 2015). It seems that *feae*-complex petrels tend to stay far from the coast, which difficults the likelihood of any beach encounters of these gadfly petrels. Finally, their tiny populations certainly further contribute for its rarity in non breeding feeding areas and the absence of records in the southwestern Atlantic Ocean.

We endorse, for a better understanding of Brazil offshore seabird movements, systematic surveys are essential, with planned expeditions throughout the year in several regions. It is highly probable that several other previously unrecorded seabird species will be encountered or could change status of occurrence (e.g., Valls et al. 2021) based on further oceanic expeditions. Both sightings presented here are from data-based citizen science. Similar to previous studies on land (e.g., Barbosa et al. 2021), records discussed here highlight the importance of citizen science for the improvement of ornithology in Brazil and elsewhere.

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Declarations

Research involving human participants and/or animals Not applicable.

Informed consent The study is all original research carried out by the authors. All authors agree with its content and submission to the journal.

Conflict of interest The authors declare no competing interests.

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