PROCELLARIIFORMS OF MARANHÃO: FIELD DATA ON SPECIES OCCURRENCE AND PHENOLOGY IN A NORTHERN BRAZILIAN COAST

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ABSTRACT

Procellariforms are pelagic seabirds found worldwide. They are more abundant in cold waters, but several species are found in tropical oceans. They are not expected to be abundant in Northern Brazil, but even this being true, a number of birds should be found in the region. So, the small number of reports suggest that the region has been strongly undersampled. Between 2008 and 2016, I have performed 20 land-based and 10 fishing boat daily surveys in Central Maranhão coast, in several sites between Maiaú Island and Caburé beach. I have included also some previous occasional records, and compared all these data with the few available reports from the literature. Indeed, procellariform numbers were not high; however, I found around 120 birds from nine species. Among them, birds from the *Calonectris diomedea* group (either *C. borealis*, *C. edwardsii*, or both) seemed to be regular in the region as a small wintering population in December and January. *Oceanites oceanicus* could be regular in small numbers as a post-breeding migrant in April. And *Ardenna gravis* has been reported several times, but up to now data are insufficient to show any well defined phenological pattern.

Keywords: Geographic Distribution, Migration, Pelagic seabirds, Phenology.

RESUMO

Procellariiformes são aves pelágicas encontradas no mundo todo. São mais abundantes em águas frias, mas várias espécies encontram-se nos oceanos tropicais. Não é esperado que sejam abundantes no Norte do Brasil mas, ainda assim, certo número de aves deveria ser encontrado na região. Portanto, os poucos registos disponíveis sugerem que a região tem sido fortemente subamostrada. Entre 2008 e 2016, realizei 20 inspeções de um dia desde ponto fixo na costa, e 10 viagens de um dia em barco pesqueiro na costa central do Maranhão, em vários sítios entre a Ilha de Maiaú e a Praia de Caburé. Incluí alguns registros prévios ocasionais, e comparei todos esses dados com os poucos registros disponíveis na literatura. De fato, o número do Procellariiformes não foi alto; entretanto, encontrei aproximadamente 120 aves pertencentes a nove espécies. Dentre elas, aves do grupo *Calonectris gr.diomedea* (ora *C. borealis*, *C. edwardsii*, ou ambas) pareceram ser regulares como uma pequena população invernante em dezembro e janeiro. *Oceanites oceanicus* pode ser regular em pequenos números como migrante pós-reprodutivo em abril. E *Ardenna gravis*

foi registrada algumas vezes, mas até agora os dados são insuficientes para mostrar um padrão fenológico bem definido.

Palavras-chave: Aves Pelágicas, Distribuição Geográfica. Fenologia, Migração.

INTRODUCTION

The order Procellariiformes comprises around 140-150 species in four families (Estandía *et al.* 2022) of pelagic seabirds found worldwide. They can be either large (albatrosses, Diomedeidae), medium (most shearwaters and petrels, Procellariidae) or small-sized birds (southern storm-petrels, Oceanitidae and northern storm-petrels, Hydrobatidae). Most of them are long-distance migrants whose movements follow the main oceanic currents, performing complex flight pathways (e. g. González-Solís *et al.* 2007, Dias *et al.* 2011, Rayner *et al.* 2011, Ramos *et al.* 2015, McDuie & Congdon 2016, Campioni *et al.* 2019). Thus, species breeding in one hemisphere may perform trans-equatorial migrations or overwinter in tropical waters (e. g. González-Solís *et al.* 2007, Dias *et al.* 2011, Rayner *et al.* 2011, Ramos *et al.* 2015, Campioni *et al.* 2019); and tropical breeding species may or may not perform long-distance migrations, but when they do, their movements can follow complex pathways as well (Ramos *et al.* 2015, McDuie & Congdon 2016). As warm tropical pelagic waters are usually much less productive than cold waters (e. g. Sigman & Hain 2012, McDuie & Congdon 2016, http://oceancolor.gsfc.nasa.gov., http://www.nodc.noaa.gov), procellariforms are found in higher numbers in cold waters (e.g. Lockley 2017), but several species can be found also in tropical waters (del Hoyo & Collar 2014).

Northern Brazilian coastline is about 2,700 km long, laying from West-Northwest to East-Southeast, between Oyapoc River (4° 27’ N, 51° 35’ W), and Calcanhar Cape (5° 10’ S, 35° 29’ W) (Figure 1) (https://pt.wikipedia.org/wiki/Litoral_do_Brasil). On the other hand, in the central and western parts of this region (from Oyapoc River to Parnaíba River, 2° 45’ S, 41°47’ W) coastal waters are mostly muddy mangrove waters, far more productive than open sea (e. g. Azevedo *et al.* 2008, Pardal *et al.* 2011), but turbid and mostly useless for procellariform foraging. Actually, the region from the Parnaíba River to the Guianas is part of the North Brazil Shelf Large Marine Ecosystem (LME), a large region of the equatorial Atlantic with warm tropical oligotrophic waters (Isaac & Ferrari 2017). Procellariforms are expected to be scarcer there than in cold waters, and unlikely to sight from the coastline, especially where coastal waters are turbid. However, as said above, a number of birds from some species should be found, and the very few available reports on procellariform occurrence for such an extensive region of the equatorial Atlantic (for example, only 35 records for the entire order in the whole Northern Brazilian coast, six of which in Maranhão, in gbif.org) suggest that the region has been strongly undersampled. Seeking to fill this gap in procellariform sampling, I conducted several field explorations in Maranhão coast, in the central region of Northern Brazilian coast, in order to obtain some field data on procellariform occurrence and phenology in those waters.

MATERIAL AND METHODS

The work was carried out in the central region of Maranhão State coastline, around the central region of Northern Brazilian coast, between 1° 10’ S, 45° 00’ W and 2° 35’ S, 42° 40’ W (Figure 1), covering a coastline of about 400 km. That coast is highly indented with turbid mangrove waters, so it is likely to sight procellariforms from the coast only in some prominent spots. This region corresponds to the eastern edge of the North Brazil Shelf LME. The continental shelf in this region is between 70 and 200 km wide, becoming wider from southeast to northwest.

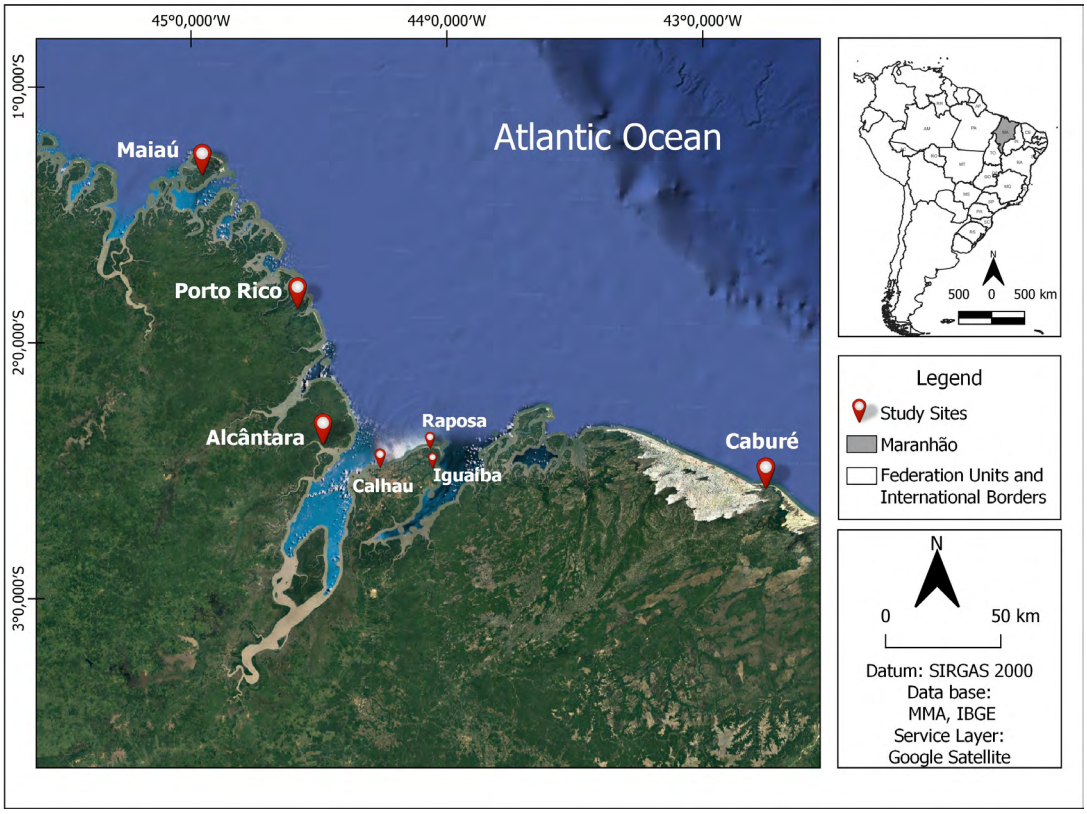


Figure 1. Sampled sites in Maranhão, in Northern Brazilian coast.

Twenty daily surveys were performed from two prominent land spots between 2008 and 2016, while ten daily surveys were performed by fishing boat between 2010 and 2016, in several different sites. In every survey, the survey time was around eight hours, spread throughout the morning and afternoon. The surveys were always carried out, regardless of the weather, on days with good visibility. Both boat and land surveys were conducted at different seasons of the year (Table 1).

Tabela 1. Number of land and boat surveys by month

MONTH	J	F	M	A	M	J	J	A	S	O	N	D
LAND	4		4		2		2		2		2	4
BOAT			1	3	1		1				1	3

The locations of the land spots were: one survey on Maiaú Island northern coast (1° 17' S, 44° 53' W), and 19 surveys on Caburé beach, close to Preguiças River mouth (2° 34' S, 42° 42' W) (Figure 1).

Boat surveys covered several square miles, usually two to five miles from shore. Latitude and longitude are given for each departure harbor: seven surveys from Porto Rico do Maranhão harbor (1° 55' S, 44° 37' W), one survey from Apicum-Açu harbor, close to Maiaú Island (1° 31' S, 45° 00' W), one from Raposa harbor (2° 25' S, 44° 06' W), and one from Iguaíba harbor (2° 33' S, 44° 05' W) (Figure 1).

Some previously extant records were also included in order to report some additional species.

And finally, all records were compared with the few previously available field data in the literature. In most cases, those data did not come from field observations published in peer-reviewed literature, but either from tracked animals in open sea or from individual field data available on digital platforms.

RESULTS AND DISCUSSION

No Procellariform species was found in high numbers (which would mean hundreds, thousands, or even more individuals for many species and sites worldwide) on Maranhão coast. But some species were found in higher numbers than that which could be expected from the scarcity of records in the literature. In addition, data from this study suggest that a few species (see below) could not only be regular, but also show regular phenological patterns. It should be noted, in any case, that procellariforms are pelagic birds that are more likely to be found in higher numbers in waters more distant to coastline than those which were reached in the samplings of the present study.

On the other hand, the bibliographical review did not find field data from peer-reviewed literature, except in one case (Carvalho *et al.* 2010, see below). However, some birds have been reported for those waters using tracking devices (González-Solís *et al.* 2007, Ramos *et al.* 2015, gbif.org). Moreover, some observational field data are available as individual data in digital platforms (gbif.org, wikiaves.com.br). Field observations in this study sometimes matched the phenological data found in the literature, but sometimes not, especially for tracked birds in open sea.

Around 120 procellariform birds were recorded in 30 systematic daily surveys on Maranhão coast between 2008 and 2016, corresponding to at least five different species: *Calonectris edwardsii*, *Calonectris borealis* (these two species belonging to *Calonectris gr. diomedea*), *Ardenna gravis* (Procellariidae); *Oceanites oceanicus* (Oceanitidae); and *Hydrobates gr. castro* (Hydrobatidae). Four additional species had been recorded previously (from 1995 to 2003), but were not found in systematic surveys during this study: *Procellaria cinerea*, *Pterodroma gr. feae* (probably *deserta* or *madeira*), *Bulweria bulwerii* (Procellariidae); and *Hydrobates leucorrhous* (Hydrobatidae). A tenth species (*Calonectris diomedea*, nominal form of *C. gr. diomedea*, mentioned above, Procellariidae) is yet to be confirmed. And an eleventh species (*Thalassarche chlororhynchos*, Diomedeidae) had been previously reported in the literature (Carvalho *et al.* 2010) but has not been found during the samplings of the present study.

I have classified all of these species into three different categories, in function of their status in Maranhão coast:
a) Species considered as probably regular at least during some period of the year. Species into this category met at least two criteria: first, they were reported in two or more of the regular surveys in this study, and second, occurrences combining data from this study and the literature reported at least six individuals. Four species met these criteria: *C. borealis*, *C. edwardsii*, *O. oceanicus* and *A. gravis*. The case of *C. diomedea* will be discussed below.

b) Species that can be either occasional or regular in small numbers. Species into this category were reported one single time (and a single individual) in this study, with two or three additional individuals having been reported in the previous literature in Maranhão. Two species were included into this category: *H. leucorhous* and *B. bulwerii*.

c) Species considered as occasional. Species into this category were reported a single time, and a single individual in this study, with no additional report in the literature. Three species were included into this category: *H. gr. castro*, *P. gr. feae* and *P. cinerea*. The only species from the literature which has not been found in this study, *T. chlororhynchos*, could be included into this category.

All of these species will be discussed separately.

a) *Species considered as probably regular at least during some period of the year*

Calonectris gr. diomedea

The *Calonectris diomedea* group currently includes *C. diomedea*, *C. borealis* and *C. edwardsii* (del Hoyo & Collar 2014). Under favorable conditions, these species can be

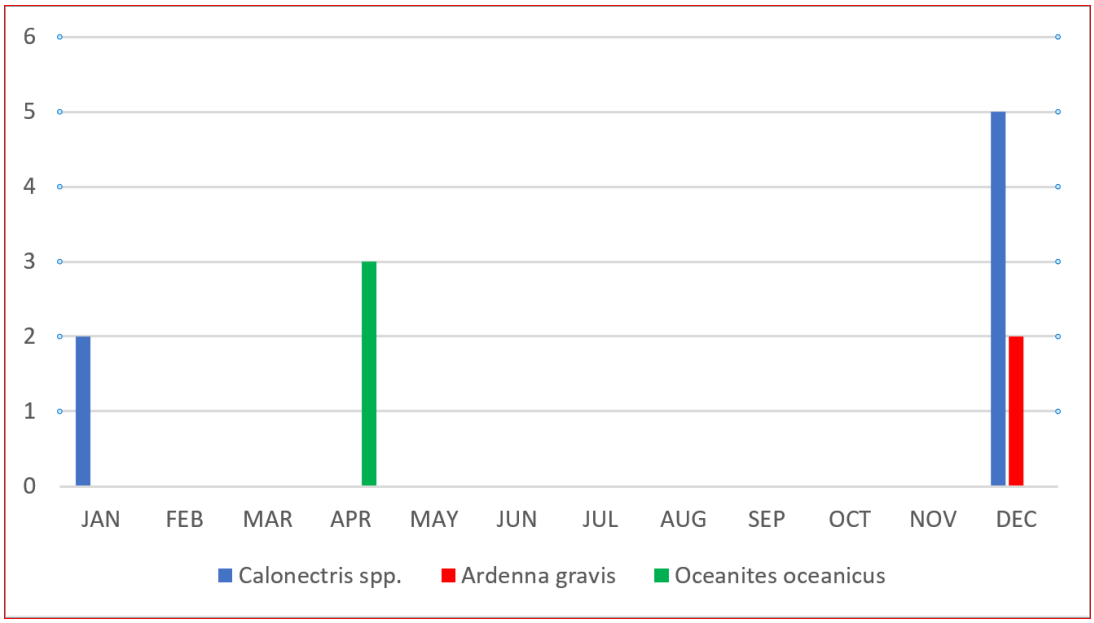
identified at sea (Porter *et al.* 1997, Flood & Gutiérrez 2021). However, distant sightings must remain at the genus level, so the birds of this group will be discussed together, despite a few things can be said at species level.

Around 80 birds from this group were recorded in seven daily surveys, both from land and boat in three different seasons (2008-2009, 2010-2011, and 2015-2016), in Caburé and Porto Rico (Table 2).

Tabela 2. Number of individuals (excluding literature) and surveys, site of record, inferred status and breeding grounds of reported procellariform species in Maranhão. CAB, Caburé; PR, Porto Rico; SMB, São Marcos Bay; CALH, Calhau Beach; MI, Maiaú Island; AL, Alcântara; LIT, Literature. Wint, wintering; PreBM, pre-breeding migrant; NonBr, non-breeding (not-yet-defined phenology); PostBM, post-breeding migrant; RR, rare but possibly regular; OC, occasional. AMC, Azores, Madeira and Canary Islands; CV, Cape Verde; TC, Tristan da Cunha; SANT, Sub-Antarctic Atlantic; SART, Sub-Arctic Atlantic. (*): only for regular and possibly regular species. (**): specific data for C. borealis and C. edwardsii are also included in the general data for C. gr. diomedea.

SPECIES	Nº	Nº	SITES		BREEDING GROUNDS (*)	
Calonectris gr. Diomedea		7	CAB, PR, LIT	Wint, PreBM		(**)
_*borealis*	2+	2+	CAB, LIT	Wint, PreBM	AMC	
_*edwardsii*	6+	3+	CAB, PR	Wint	CV	
Ardenna gravis	4+	2+	CAB, LIT	NonBr	TC	
Oceanites oceanicus	12	3	PR, SMB	PostBM	SANT	
Hydrobates leucorhous	1	-	CALH, LIT	RR	SART	
Bulweria bulwerii	1	-	MI, LIT	RR	AMC, CV	
Hydrobates gr. castro	1	1	PR	OC		
Pterodroma gr. feae Procellaria	1	-	AL	OC		*deserta / madeira*
cinerea Procellariidae	1	-	CALH	OC		
i. s.		4	CAB			*Calonectris / Ardenna*

Figure 2. Number of surveys (either boat or land) by month when the most regular procellariiform species were reported in Maranhão coast.



A maximum of around 30 different individuals was recorded in a single survey (Caburé, December 31st 2008). All records occurred between December 15th and January 2nd (Figure 2).

Most birds could not be identified to species level. From the few birds identified to species, six were *C. edwardsii* and two *C. borealis* (Table 2), while *C. diomedea* identification remained probable. In several cases, some birds could be identified as *borealis*/*diomedea*, being unmistakably non-*edwardsii*. Also, some 20 "shearwater" distant sightings could correspond either to *Calonectris* or *Ardenna* birds (see below), all of them from land in Caburé in December-January. Throughout the entire study, no bird flock was recorded, and birds were flying alone in all cases. Therefore, high bird numbers would not correspond to occasional big flocks, but to scattered individuals distributed over an extensive sea surface. This scattered distribution at sea is the strongest evidence in favor of a regular pattern of occurrence for at least some of the species of this group in Maranhão.

In the literature, from a sample of 22 *Calonectris* birds from Azores, Canary and Mediterranean colonies, at least three marked birds from Canary Islands (currently classified as *C. borealis*) were reported for Northern Brazilian coast, in front of Maranhão waters (González-Solís *et al.* 2007), after wintering in Southern Atlantic. These records correspond to pre-breeding migration, which occurs around March, so they do not match December-January coastal sightings in this study, which could correspond to wintering birds. Pictures of *C. borealis* by different authors can be found in WikiAves website (www.wikiaves.com.br) for several northern Brazilian spots, being six records from Maranhão, named as São Luís (three photographs by M. Spinelli), and Barreirinhas (three photographs by M. Olio), corresponding to the period from November 2011 to January 2012. It should be noted that reports named as "São Luís" in WikiAves would rather correspond to a spot close to what I have called Raposa in this study. Similarly, "Barreirinhas" reports would actually be close to the same spot I have called Caburé. Therefore, these reports are similar to sightings reported in this study. Additional coastal records from neighbor regions in Northern Brazil can be found on the platforms (gbif. org, wikiaves.com.br); all coastal reports occurred between November and February of several different years.

Numbers as high as 80 scattered birds, reported in the present study, seem to correspond to a wintering population a little larger than might have been thought previously. On the other hand, data from tracked trans-equatorial migrant birds do not point to Northern Brazilian waters as a main wintering area, but as part of a pre-breeding migration corridor (González-Solís *et al.* 2007, Dias *et al.* 2011, Reyes-González *et al.* 2017, Campioni *et al.* 2019). Thus, Maranhão – and Northern Brazil in general – could be a secondary, but not occasional, wintering ground for a few birds, and part of a migration corridor for most birds wintering in the Southern Hemisphere. This group of species showed what can be considered the most reliable phenological pattern in the present study.

It is worth mentioning that most of the confirmed records from the different forms of literature do not identify *Calonectris* birds to species; but when that happened, all of the reported birds corresponded to *C. borealis*; so, despite the present study having reported more *C. edwardsii* birds, *C. borealis* could be the most abundant of all the species of the group in Maranhão, specially when several birds were borealis/diomedea, and non-edwardsii. Still, the case of *C. diomedea* demands further data, as the first reports of the group in the literature were identified as *C. diomedea*, before splitting the current species. It possibly occurs in the region, but further data are needed to estimate its status. In any case, Reyes-González *et al.*(2017) identified the non-breeding areas of the Spanish populations of both *C. borealis* (mostly breeding in Canary Islands) and *C. diomedea* (western Mediterranean); they found that the wintering areas of *C. diomedea* in the Equatorial Atlantic were located a little more eastwards than those of *C. borealis*, which would mean outside Maranhão. That would mean that *C. diomedea*, if occurring in Maranhão waters, would likely be much rarer than *C. borealis*.

Oceanites oceanicus

Oceanites oceanicus was reported in two daily boat surveys, on April 15th and 16th 2011 in Porto Rico, with an additional previous record on April 21st 2001 at sea, in São Marcos Bay near Calhau beach (2° 30' S, 44° 20' W) (Figure 2). All birds numbered 12 (Table 2). As in the previous species, all reported birds were flying alone and scattered across the sea surface, indicating that they did not correspond to the occasional occurrence of a large flock.

Storm Petrels (Oceanitidae and Hydrobatidae) are small sized birds that have begun to be marked with tracking devices only in most recent years. Therefore, so far, *O. oceanicus* has not been reported in Maranhão using tracking devices. There are no sighting records in Maranhão, except for this study, but a number or sighting records is available on the platforms (gbif.org) for neighbor regions, in Northern Brazil, and especially in the Guianas, at different times of the year. April birds in this study would correspond to post-breeding migrants, flying to the Northern Hemisphere and maybe performing short stopovers.

Ardenna gravis

At least four *Ardenna gravis* individuals were recorded in December 30th and 31st 2008 in Caburé during land surveys (Figure 2; Table 2). As said above, around 20 "shearwater" distant sightings could correspond either to *Calonectris* or *Ardenna* birds, so *A. gravis* numbers could be a little higher than what is reported here. Also in this case, all birds were flying alone.

In addition, some *A. gravis* birds have been reported using tracking devices in open sea waters in front of Northern Brazilian coast. However, also for this species, those records do not match December coastal sightings: one or more birds remained in front of Maranhão waters in September 2019, and some additional birds remained from May to July 2010 (gbif.org). The phenology of coastal sightings in the literature is similar to what has been observed in this study: one picture of *A. gravis* also corresponds to December 2011 in Barreirinhas (M. Olio), close to Caburé, and two additional coastal records in waters neighboring Maranhão correspond to December 2012 and January 2013 (gbif.org). As *A. gravis* is a Southern Hemisphere breeding species, the reported coastal sightings could either match the very beginning of the post-breeding migration, or correspond to non-breeding juvenal or subadult birds. In any case, for this species, coastal reports are scarcer than for the previous ones, and clear phenological patterns do not arise from either sighted or tracked birds, until further data are collected.

b) *Species that can be either occasional or regular in small numbers.*

Hydrobates leucorhous

This species was not found during the systematic surveys. The only occurrence provided in this study corresponds to a shored bird in Calhau beach (2° 29' S, 44° 16' W), March 2003 (A. A. F. Rodrigues, pers. com.) (Table 2). Along with this report, three additional coastal records are found in the platforms for Maranhão (two of them near Pará State, 1° 00' S, 46° 05' W, and one in São Luís) (gbif.org, wikiaves.com.br). Also, a number of sighting records for this species can be found in the platforms in neighbor waters. These data are insufficient to define if this species is, either occasional, or maybe regular in small numbers.

Bulweria bulwerii

As for the previous species, this bird was not found during the systematic surveys. The only occurrence provided in this study corresponds to one bird observed at sea from Maiaú Island, March 1999 (Table 2). On the other hand, *Bulweria bulwerii* birds breeding mostly in Azores, Salvage, Canary and Cape Verde, spent their non-breeding season mostly in Central-Western Atlantic, with a small number of birds reaching the Northern Brazilian coast, mainly in its easternmost part, and being the open sea in front of Maranhão the westernmost area for a few birds (Ramos *et al.* 2015).

A number (in this case a small number) of sighting records have been reported from neighbor regions, especially to the East. As in the preceding species, this bird could be either occasional, or regular in small numbers in the region.

c) *Species considered as occasional*

One bird from *Hydrobates castro* group (Hydrobatidae) was recorded in Porto Rico in April 16th 2011 (Table 2). The species from this group are completely cryptic at sea (Taylor *et al.* 2019), so I prefer not to speculate on which precise species could correspond to the sighted bird. This was the only species considered as occasional that was found during systematic surveys, yet the absence of any other report made it more likely to keep this species in category c). However, a number of reports from French Guiana (gbif.org) demands attention to the species of this group in the future.

One bird from *Pterodroma feae* group was observed at sea near Alcântara harbor (2° 15' S, 44° 25' W), September 1995 (Table 2). Species from this group are not completely cryptic, but are difficult to identity at sea (Shirihai *et al.* 2010). The reported bird should be most likely attributed to *deserta*, or less probably the much scarcer *madeira* (both endemic to the region of Madeira and Desertas Archipelagos), since *P. feae* rarely leaves its breeding grounds in Cape Verde (J. González-Solís, pers. com.). Also in this case, there are some reports of birds of this group in French Guiana (gbif.org).

One shored individual of *Procellaria cinerea* was found on Calhau beach, São Luís, April 1997 (Table 2). No previous record of this species has been found in all Northern South America.

Finally, the record of *Thalassarche chlororhynchos* by Carvalho *et al.* (2010) corresponded to Iguará Island, close to the site which has been named Maiaú Island in this study. There are no additional records of this species in the region.

To conclude, even when not found in high numbers, procellariforms appear to be more regular in Maranhão waters than might have been expected from the very scarce data found in the previous literature. From the nine procellariform species reported in this study, at least two, but probably up to four, showed what appeared to be a regular phenology. One or more *Calonectris* species could be regular as wintering birds, at least in December and early January (either *C. borealis*, *C. edwardsii*, or both), and as pre-breeding migrants, (after data from tracked birds in the literature). While *O. oceanicus* could be regular as a post-breeding migrant, at least in April. Additional data are needed to confirm whether *A. gravis* could also be regular in December and January. All phenological patterns suggested here ought to be confirmed by further data.

All of the remaining reported species seem to be rare, but the few available records suggest that small numbers of *H. leucorrhous*, and *B. bulwerii* should be searched for in Maranhão beyond the existing reports. No pattern could be even suggested about the remaining species' phenology or occurrence.

Putting together data from this study and the literature, Maranhão waters are used mainly as a migration corridor following the Atlantic currents, and to a lesser extent as a wintering or non-breeding ground for a few species. This should be taken into account when defining conservation policies, especially since some potentially impacting fishing activities, such as longlines, are very common in the region.

What is most remarkable about the few (either confirmed, or possible) regular species are their different origins: almost everywhere in the Atlantic basin (Table 2). This pattern matches what has been found for non-breeding pelagic birds more generally in Brazilian waters (Olmos 2002).

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