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Zoologia Caboverdiana é uma revista científica com arbitragem científica (*peer-review*) e de acesso livre. Nela são publicados artigos de investigação original, artigos de síntese e notas breves sobre Zoologia, Paleontologia, Biogeografia, Etnozoologia e Conservação nas ilhas de Cabo Verde. Também publicamos artigos originais ou de revisão de uma área geográfica mais ampla desde que debruçados sobre espécies que ocorrem no arquipélago de Cabo Verde.

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Nota editorial

Ano novo, vida nova

Depois de um difícil ano, o ano novo avizinha-se e a solução para a pandemia está a chegar. Tal como o solstício renova a esperança da chegada da Primavera, o novo ano leva-nos a almejar concretizar novas metas que ainda não conseguimos alcançar. Imbuídos deste espírito, a revista espera libertar-se de velhos hábitos e voar. A capa deste número é uma metáfora desse sentimento.

Neste número temos, como habitualmente, dois artigos e uma nota breve. O primeiro artigo, intitulado "*Caracóis marinhos do noroeste das ilhas de Cabo Verde: contribuição para a sua ecologia*", abre novas perspectivas sobre as características do habitat destes invertebrados endémicos. Este estudo mostra que mesmo grupos muito bem estudados do ponto de vista filogenético e biogeográfico têm ecologias pouco conhecidas. Os autores demonstram assim que, ao menos nas ilhas do noroeste, existem habitats mais diversos que o esperado para as espécies com concha pequena.

O segundo artigo refere-se ao "*Teste de translocação de cagarras de Cabo Verde* Calonectris edwardsii *no ilhéu Raso"*. Este estudo teve como objectivo verificar o efeito de ninhos artificiais no crescimento das crias e no sucesso do abandono do ninho desta ave endémica ameaçada. Os resultados revelaram-se promissores para uma possível reintrodução da espécie na ilha vizinha de Santa Luzia, onde a espécie foi extinta devido à acção humana. Espera-se que tal possa acontecer brevemente e aguardaremos pelos resultados que comprovem o sucesso da metodologia proposta.

De salientar que este são mais dois trabalhos apoiados pelo Fundo SCVZ Desertas que em breve reabrirá mais uma edição para candidaturas.

A nota breve descreve o "*Raro avistamento de orcas anãs* Feresa attenuata *ao largo da ilha de São Nicolau, Cabo Verde*". Esta surge em seguimento à publicação da última nota breve do número anterior, que relatava o primeiro registo oficial da orca anã no país, na ilha do Fogo. Desta vez a espécie foi avistada nas ilhas do Barlavento, sugerindo a possibilidade da existência de uma pequena população residente no arquipélago.

Por último, queria agradecer aos vários colegas que apoiam a revista e que têm incentivado o nosso esforço com boas palavras e acções. Obrigada. Desde Cabo Verde vos desejo que este ano nos traga a todos uma vida nova, mais consciente e empática. Nô te junt!

Doutora Raquel Vasconcelos
Editora-chefe da *Zoologia Caboverdiana*

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Editorial note

New year, new life

After a difficult year, the new year is approaching and the solution to the pandemic is coming. Just as the solstice renews the hope of spring arrival, the new year leads us to aim achieving new goals that we were not able to accomplish yet. Filled with this spirit, the journal hopes to break free from old habits and to fly. The cover of this issue is a metaphor of that feeling.

In this issue we have, as usual, two articles and a short note. The first article, entitled '*Cone snails on the North-Western Cabo Verde Islands: contribution to their ecology'*, opens new perspectives on the habitat characteristics of these endemic invertebrates. This study shows that even groups very well-studied from a phylogenetic and biogeographic point of view have poorly known ecologies. The authors show that, at least in the north-western islands, there are more diverse habitats than expected for small shell species.

The second article refers to the '*Translocation test of Cabo Verde Shearwater* Calonectris edwardsii *on Raso Islet*'. This study aimed to verify the effect of artificial nests on the growth of the young and on the fledging success of this endemic threatened bird. The results proved to be promising for a possible reintroduction of the species on the neighbouring island of Santa Luzia, where the species went extinct due to human action. This is expected to happen soon and we will wait for the results to prove the success of the proposed methodology.

It should be noted that these are two more works supported by the SCVZ Desertas Fund, which soon will reopen one more call for grants.

The short note describes the '*Rare sighting of pygmy killer whales* Feresa attenuata *off São Nicolau Island*, *Cabo Verde*'. This follows the publication of the last short note of the previous issue, which reported the first official record of pygmy killer whales in the country, on the island of Fogo. The species was seen in the Windward Islands this time, suggesting the possibility of a small resident population in the archipelago.

Finally, I would like to thank the various colleagues who support the magazine and who have encouraged our effort with good words and actions. Thanks. From Cabo Verde I wish you this year will bring us all a new, more conscious and empathic life. Nô te junt!

Doutora Raquel Vasconcelos
Editor-in-chief of *Zoologia Caboverdiana*

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Artigo original | Original article

Cone snails on the North-Western Cabo Verde Islands: contribution to their ecology

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RESUMO

Os caracóis marinhos (família Conidae) são um dos grupos mais abundantes de invertebrados marinhos vivos e um contribuinte essencial para a biodiversidade marinha. Os caracóis marinhos são encontrados comumente e amplamente distribuídos por todas as áreas tropicais dos oceanos. São espécies com deslocação muito lenta que normalmente ficam no mesmo local grande parte da vida. O habitat mais comum destes caramujos ocorre nas margens dos recifes de coral. Em Cabo Verde, vários atributos observados das populações estão de acordo com as expectativas de um modelo de características ecológicas de pedras, areias e recifes proposto por Rolán (2005). Embora estudos importantes confirmem a diversidade, origem e distribuição com base na filogenia molecular dos caracóis marinhos de Cabo Verde, o habitat e a ecologia básica destes permanecem pouco compreendidos, principalmente nas ilhas do noroeste. Neste trabalho, amostrámos várias novas áreas, analisámos características morfológicas e o habitat dos caracóis marinhos. A morfologia dos habitats é variada. No entanto, a adaptação a novos habitats parece promissora. Neste trabalho, propomos quatro diferentes tipos de habitat para os caracóis marinhos de Cabo Verde nas ilhas do noroeste, onde incluímos dois novos habitats, em contraste com o observado noutras ilhas do arquipélago.

Palavras-chave: *Africonus, Conus*, endémico, habitat, marinho

ABSTRACT

Cone snails (family Conidae) are one of the most abundant groups of living marine invertebrates, and an essential contributor to biodiversity in the sea. Cone snails are commonly found and extensively distributed throughout all tropical oceans. They are very slow-moving species that typically stay in the same location for most of their lifetime. Their most common habitat occurs on fringing coral reefs. In Cabo Verde, several attributes of the observed populations conform to expectations of a model of ecological characteristics of stones, sands, and reef proposed by Rolán (2005). Although significant studies confirm the diversity, origin, and distribution based on molecular phylogeny of the Cabo Verde cone snails, their habitat and basic ecology remain poorly understood, mainly in the north-western islands. In this study, we sampled various new areas, analysed morphological characteristics of cone snails and their habitat. The morphology of the habitats is varied. However, adaptation to new habitats looks promising. In this work, we propose four types of habitat for Cabo Verde cone snails in the north-western islands, where we include two new habitats, in contrast to what was observed in other islands of the archipelago.

Keywords: *Africonus*, *Conus*, endemic, habitat, marine

INTRODUCTION

Cone snails are tropical marine gastropods belonging to the Conidae family (superfamily Conoidea). Recent literature has suggested the existence of approximately ~800 living species (Olivera *et al.* 2014, Puillandre *et al.* 2014, Tenorio *et al.* 2020). Cone snails are among the most abundant groups of living marine invertebrates and an essential contributor to biodiversity in the marine realm, commonly found and extensively distributed throughout all tropical oceans (Duda & Kohn 2005). They are very slow-moving, typically inhabiting the same location for most of their lifetime. They can be classified based on their primary prey (Puillandre *et al.* 2012, 2014): the vermivorous species that eat polychaetes, hemichordates, and echiuroid worms (worm-hunters), molluscivorous species that hunt other mollusks (snail hunters), or piscivorous (fish hunters). The endemic cone snails in Cabo Verde are vermivorous, considering their radula (Cunha *et al.* 2005).

The Cabo Verde Archipelago is a cone snail hotspot in the Atlantic Ocean with 52 mostly stable species, of which 49 are endemic – a much higher diversity than anywhere else in the Atlantic Ocean (Monteiro *et al.* 2004, Duda & Rolán 2005, Rólan 2005, Khon *et al.* 2014). In Cabo Verde, the great variety of cone snail species represents about 10% of the global species diversity (Monteiro *et al.* 2004). The species considering in this study are not treated in a taxonomically consistent manner in the literature. Considering the recently reconstructed phylogeny, the analysed species in this work belong to the *Africonus* subgenus, sister taxa to *Lautoconus* (Abalde *et al.* 2017, Tenorio *et al.* 2020).

Rólan (2005) performed the first comprehensive work in Cabo Verde cone snails. The significant numbers of endemic species are consistent with an independent colonization event by 'small-shelled' and 'large-shelled' cone snail lineages (Cunha *et al.* 2005). Although a significant number of studies confirm the diversity, origin, and distribution of cone snails based on molecular phylogeny (Abalde *et al.* 2017, Cunha *et al.* 2005, Manuel *et al.* 2017), their basic ecology, such as the essential habitats, remains poorly understood.

The Cabo Verde Islands (Fig. 1) were formed by rock accumulation from volcanic eruptions, and they are located in the eastern central Atlantic, around 570 km from the West African coast. Cabo Verde is rocky underwater and covered by several reef organisms referred to as coralline community (Almeida *et al.* 2007). The north-western islands of Santo Antão, São Vicente, and Santa Luzia (the latter is a marine reserve) are located on the second largest insular shelf of Cabo Verde, one of the areas with the richest marine biodiversity in the archipelago (Almeida *et al.* 2015, Freitas *et al.* 2015), also for cone snails (Duda & Kohn 2005). The cliffs and rocky areas on the northern and north-eastern regions are exposed to constant wave action, especially on Santa Luzia. The southern and south-western areas of those latter islands are mostly flat. They have beaches and sandy bottoms, as well as rhodolith beds which are partially covered in the sub-tidal zone (Freitas *et al.* 2015), thus with more areas suitable for the occurrence of cone snails (Rólan 2005). For this reason, we have chosen those islands to perform a study on the habitat characterization for Cabo Verdean snails. The objectives of this work were: (i) characterize the habitat and (ii) contribute to reshaping the spatial distributions of the cone snails in the North-Western Islands of Cabo Verde.

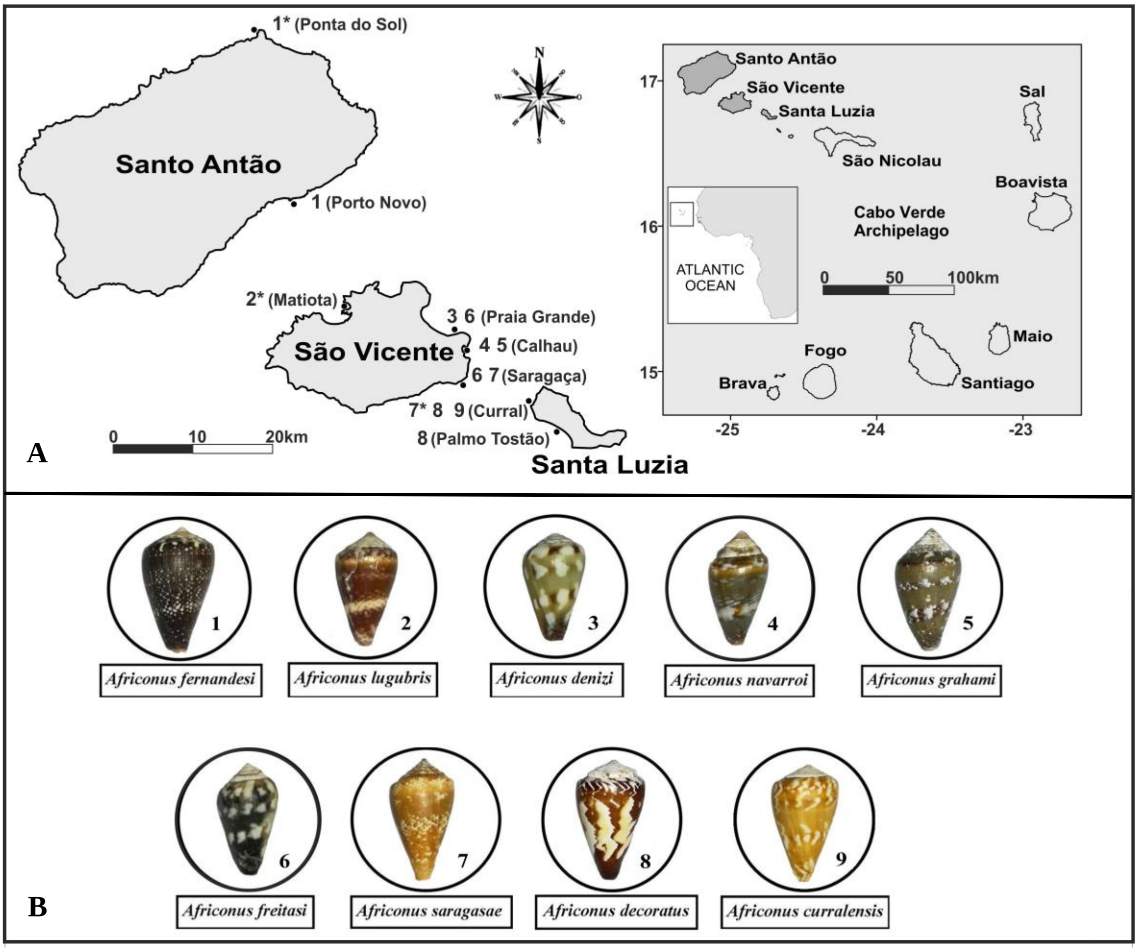

Fig. 1. Sampling sites and sampled species. **A)** Sites on the North-Western Islands in the Cabo Verde Archipelago (marked in grey on the right) where sampling took place are marked in parentheses. **B)** Sampled species. The figures correspond to the species found in each site, also detailed in Table 1. The numbers marked with an asterisk correspond to records of empty shells of cone snail species. Check Results for further details.

MATERIAL AND METHODS

The field studies routines here were made during several scientific expeditions on the North-Western Islands of Cabo Verde (Fig. 1): Santo Antão (Porto Novo and Ponta do Sol), São Vicente (Laginha, Salamansa, Praia Grande, Calhau, Saragaça and Fateja bay) and Santa Luzia (Água doce, Curral, Palmo Tostão beach, nearby Zinho Islet, Portinho, Francisca beach, Praia dos Achados beach and Gurajona bay), from May 2016 to July 2018. The collection of cone snail samples was mostly performed through snorkelling dives (in the evening), from May to July in 2016 and 2017, in small and shallow water bays. During the dives, we searched for the cone snails under rocks, between rock cracks, half-buried in the sand, and between corals or algae. A total of 134 shells samples were collected during several expeditions and included in the present work. Most shells were collected during dive sampling. Specimens that were found alive in the wild were measured and identified *in situ* and then returned to their natural habitat, with only one specimen kept alive for genetic work, according to the recommendation of Tenorio *et al.* (2017).

For the description of the shells, their shape and sculpture were firstly used, followed by the same morphological variables) as Röckel *et al.* (1995), and Tenorio *et al.* (2017). Other morphologic data was retrieved from Tenorio *et al.* (2017), such as data of *Africonus freitasi*, *Africonus miruchae*, and *Africonus denisi*, and compared with our specimens and the specimens from the reference collection on cone snails of the Technical University of the Atlantic (UTA) in Mindelo, Cabo Verde, for species identification. The colouration patterns presented by each species have been described based on the way pigments are deposited, depending on the shape and size of each shell.

The cone snail habitats were characterized according to their physical aspect, the presence of surrounding organisms identified during the dives (free and SCUBA) and photos taken underwater. We described the surveyed habitats based on their surface geomorphological features and the model habitat classifications for cone snails proposed by Kohn & Nybakken (1975).

RESULTS

The results of the morphological traits (shell sizes and pattern) of cone snail species (Table 1), their distribution (Fig. 1 and Table 2), and habitat characterization (Fig. 2) are presented in the following paragraphs.

All the nine cone snail species found in our sampling belong to the *Africonus* clade and belong to the small-shelled species, based on the Cunha *et al.* (2005) classification, as cone snail individual sizes presented maximum shell lengths below 29 mm (Table 1). These cone snails were found in the three studied islands (Table 2) in sites with similar morphological characteristics but with different physiological features. The observations made from field and photo records led to the classification of four habitat types for cone snails, depicted and characterized in Fig. 2.

Table 1. Studied cone snail species. The minimum, maximum, average, and standard deviations values of each shell morphology variables (SL, maximum shell length; MD, maximum diameter; AH, aperture height; SH, spire height; MDH, MD height; PMD, relative position of maximum diameter; RD, relative diameter; RSH, relative SH; all in mm) for each species are presented (in mm; n stands for the number of specimens). Standard colouration patterns (shell) are also depicted.

Species		SL	MD	AH	SH	MDH	PMD	RD	RSH	Shell
1. *Africonus fernandesi* (n= 12)	Average	21.79	13.93	19.28	3.73	17.97	0.93	0.72	0.17	
	SD	2.24	1.51	1.68	0.75	1.66	0.06	0.04	0.02	
	Maximum	25.80	16.70	21.50	3.90	19.60	0.97	0.80	0.19	
	Minimum	18.70	12.80	17.50	2.10	15.20	0.76	0.67	0.11	
2. *Africonus lugubris* (n= 8)	Average	19.80	11.55	15.44	3.76	16.04	1.06	0.77	0.19	
	SD	4.78	2.83	4.83	0.94	4.00	0.17	0.14	0.03	
	Maximum	26.60	15.60	22.40	5.20	21.40	1.34	1.03	0.23	
	Minimum	12.80	7.30	10.10	2.40	10.20	0.96	0.67	0.15	
3. *Africonus denizi* (n=27)	Average	11.62	6.80	9.90	2.25	9.38	0.95	0.68	0.19	
	SD	1.41	0.87	1.25	0.46	1.23	0.05	0.02	0.03	
	Maximum	13.80	8.10	11.90	3.00	11.20	1.00	0.74	0.28	
	Minimum	9.00	5.30	7.90	1.50	7.40	0.85	0.63	0.15	
4. *Africonus navarroi* (n=22)	Average	12.89	7.05	10.62	3.69	9.20	0.87	0.67	0.29	
	SD	2.97	1.67	2.57	0.91	2.25	0.08	0.03	0.04	
	Maximum	18.30	9.60	14.70	6.10	12.70	1.01	0.75	0.36	
	Minimum	8.00	4.40	6.50	2.30	5.70	0.57	0.61	0.21	
5. *Africonus grahami* (n=27)	Average	22.16	11.89	18.33	5.07	17.10	0.93	0.65	0.23	
	SD	2.56	1.71	2.31	0.71	2.28	0.03	0.03	0.03	
	Maximum	27.10	16.00	22.60	6.30	21.20	0.98	0.74	0.29	
	Minimum	16.30	8.60	13.80	3.50	12.80	0.87	0.58	0.17	
6. *Africonus freitasi* (n= 13)	Average	12.73	7.22	10.72	2.02	10.72	1.00	0.67	0.16	
	SD	1.59	1.22	1.44	0.36	1.44	0.00	0.03	0.03	
	Maximum	15.90	9.60	13.70	2.70	13.70	1.00	0.71	0.21	
	Minimum	10.80	5.60	8.80	1.40	8.80	1.00	0.60	0.13	
7. *Africonus saragasae* (n=2)	Average	20.35	9.45	16.90	3.55	16.95	1.01	0.57	0.18	
	SD	0.21	2.05	1.27	0.64	0.64	0.04	0.16	0.04	
	Maximum	20.50	10.90	17.80	4.00	17.40	1.03	0.68	0.20	
	Minimum	20.20	8.00	16.00	3.10	16.50	0.98	0.45	0.15	
8. *Africonus decoratus* (n= 10)	Average	23.30	13.41	19.81	3.87	19.41	0.99	0.68	0.17	
	SD	3.11	2.23	3.18	1.24	2.48	0.06	0.03	0.05	
	Maximum	28.20	16.80	24.10	5.50	23.50	1.09	0.75	0.24	
	Minimum	18.70	10.40	16.00	2.10	16.60	0.92	0.63	0.09	
9. *Africonus curralensis* (n= 13)	Average	16.98	9.87	14.80	1.80	15.18	1.08	0.69	0.10	
	SD	1.93	1.15	1.80	0.72	1.52	0.03	0.03	0.04	
	Maximum	20.20	11.50	17.70	3.10	17.70	1.09	0.71	0.16	
	Minimum	10.80	5.10	9.00	0.50	9.30	0.99	0.57	0.04	

Fig. 2. Habitat types studied, organized in four types. **A)** Type I habitats have an extensive area of corals (most are of *Zoanthus* species) with a skinny 2 m-layer of sand in the cracks. **B)** Type II habitats present a high abundance of algae at about 2–5 m deep, small coralline communities that vary widely in substrate types from complex living coral substrates to dead coral zones, and boulders, with a skinny layer of sand. **C)** Type III habitats are predominantly filled with stones surrounded by a thin layer of sand, covered with a thin layer of algae, few crusted corals, and harbouring many organisms mostly shells and polychaetes (1–2 m). **D)** Type IV habitats are typical on the beach areas with stones and large slabs with brown and green algae, and located in areas of constant wave breaking, and of few centimetres of depth. Check Table 2 to complement the information regarding their location and the cone snails found in each habitat type.

Table 2. Summary of cone snail habitat types, their location, and recorded species.

Habitat	Island and locality	Species
Type I	São Vicente, Laginha	*Africonus lugubris*
Type II	Santa Luzia, Curral and Zinho Islet	*Africonus decorates*
		Africonus curralensis
		Africonus saragasae
Type III	São Vicente, Calhau	*Africonus grahami*
		Africonus navarroi
Type IV	São Vicente, Praia Grande	*Africonus freitasi*
		Africonus denizi
		Africonus fernandesi
	Santo Antão, Porto Novo	*Africonus fernandesi*
	Santo Antão, Ponta do Sol	*Africonus fernandesi*

On Santo Antão Island, the *Africonus fernandesi* specimens were collected in Porto Novo about 2–4 meters deep, in a small, sheltered bay (Fig. 1). Snorkelling in Ponta do Sol (Fig. 1) we also found six well-preserved shells of this species in a habitat remarkably similar to that of Porto Novo (habitat type IV, Fig. 1), which should be considered as a possible new record for *A. fernandesi*. Most of the species distributed in the east of São Vicente Island, namely *A. navarroi*, *A. freitasi* and *A. grahami*, were found on shores of Praia

Grande and Saragaça beach. However, Calhau was the site with a higher density of cone snails (Fig. 1 and Table 2). On this island, we also found only shells of *A. lugubris* (Fig. 1 and Table 2). On Santa Luzia, we found and collected a shell of a specimen of *Africonus curralensis* and two of *Africonus saragasae* (Fig. 1 and Table 2).

DISCUSSION

Most of the endemic cone snails of São Vicente Island (*Africonus navarroi*, *Africonus grahami*, *A. freitasi*, *Africonus saragasae*, *Africonus denizi*, and *Africonus lugubris*) are known to be distributed on the eastern shores (Tenorio *et al.* 2017). Only one endemic species has been described in the northern sites between Matiota (Porto Grande bay) and Salamansa Bay, *Africonus lugubris*, which according to IUCN has not been found alive since 1980, hence considered as presumable Extinct (Peters *et al.* 2016). Of the species known to occur in the eastern shores, we found live specimens of *A. navarroi*, *A. grahami*, *A. freitasi* and *A. denizi*, as it is challenging to find cone snails without extensive and lengthy fieldwork. Regarding the species occurring on Santo Antão, according to Tenorio *et al.* (2008), *A. fernandesi* has a broader distribution than the one we observed, from west to east of Porto Novo. Still, it was not mentioned to occur in Ponta do Sol. Hence, our observation may constitute a new locality for the species. Unfortunately, we did not find any living individuals of that species. Probably more research time is needed to find a living individual. On the island of Santa Luzia, only six endemic species were recorded, namely *A. curralensis*, *A. decoratus*, *A. grahami*, *A. santaluziensis*, *A. saragasae*, *A. navarroi* (Tenorio *et al.* 2017), but we only found and collected a shell of a specimen of *A. curralensis* (Table 1). It is challenging to find cone species on Santa Luzia, probably because of the sea turmoil.

The North-Western Islands, Santo Antão (7.5 million years, My), São Vicente (6.6 My), and Santa Luzia (7 My) are characterized by less endemic cone species and population densities than older islands, such as Sal (25.6 My), Boavista (16.6 My), and Maio (21.1 My) (Afonso & Tenorio 2011, Cunha *et al.* 2005, Cunha *et al.* 2017, Duda & Rolán 2005, Ancochea *et al.* 2015). The initial colonization and radiation of cone snails happened long after the islands were formed, so greater diversity of endemic species on older islands of the archipelago may be due to the higher prevalence of barriers to gene flow and habitats complexity related to changes in island coastlines during repeated periods of low sea levels during glacial maxima (Duda & Rolán 2005, Cunha *et al.* 2017). Therefore, access to an endemic cone population could be more challenging in the north-western islands since their coastline is less flat than on the oldest islands. In addition, the difficulty in finding some species may be associated with their reduced occupation area or small population sizes. Also, the fact that cone snail species are considered night hunters could explain why they are less conspicuous during the afternoon, when sampling was performed.

The morphological character state ‘small' is associated with species with an average individual size between 10–29 mm (Cunha *et al.* 2005, 2008). The most common species on Sal, Boavista, and Maio islands, such as *Conus (Kalloconus) venulatus* and *Conus (Kalloconus) pseudonivifer* (Cunha *et al.* 2008) are large-shelled species and were found in the sand under coral rocks in shallow bays. The habitats appear to be remarkably similar (Rolán 2005) regardless of the size of the shells of the species that inhabit it. In contrast, in the North-Western Cabo Verde Islands, we identified, for the first time, four different types of habitat. In Cabo Verde, few species were found in each habitat type; thus, we have described four types of cone snail habitats. However, the islands with the highest density of individuals have type I and II habitats as the commonest ones. According to Kohn & Nybakken (1975), habitat types are not directly related to prey type. Nevertheless, the relationship between Cabo Verde cone snail species and worm prey species has not yet been considered, increasing even more the difficulty to detect cone snails. It should be noted that supposedly cone snails seek to live in bays protected from large wave movements and where they are protected regardless of the tides (Cunha *et al.* 2005). Surprisingly, in this work, we found cone snail species in the habitat type IV, associated with constant wave breaking, such as *A. freitasi* and *A. denizi*. These species found at habitat IV have shorter shell length, suggesting that this kind of habitat does not provide refuges for larger animals from wave action at high tide (Kohn & Nybakken 1975). These physical difficulties are not encountered in subtidal habitats.

Cone snail diversity could be attributed to the multiplicity of habitats (Kohn 2001). However, the co-occurring species of cone snails in the same habitat (e.g., *Africonus fernandesi*) is due to use of different micro-habitats or probably to a greater extent of different prey species (Khon *et al.* 1975). Thus, to better understand the influence of habitat on the diversity and abundance of cone species, it is essential to develop in-depth studies at micro-habitat level and their correlation with prey types.

CONCLUDING REMARKS

Here, we identified for the first time four types of habitats for Cabo Verde cone snails, suggesting that, in the North-Western Islands of Cabo Verde, the cone snail species spread for more diverse habitats and that is probably is not related directly to their prey. We hypothesized that the evolution of behavioural, morphological, and venom biochemistry traits is the key to adaptation to different habitats. Our results also suggest that the small-shelled cone snail species can habit places with greater hydrodynamics than previously though. However, it is essential to analyse the complex ecological links and interactions in diverse coral reef and non-coral reef habitats to fully understand these new results and more data to test our hypothesis.

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Translocation test of Cabo Verde shearwater *Calonectris edwardsii* on Raso Islet

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RESUMO

A translocação de crias de aves é uma metodologia utilizada para aumentar a probabilidade de recolonização de uma área onde outrora uma espécie nidificava, como é o caso da cagarra endémica de Cabo Verde *Calonectris edwardsii* que ocorria na ilha de Santa Luzia. Para que esta translocação seja exitosa, é importante primeiro verificar a aplicabilidade da mesma. Assim, este estudo teve como objectivo verificar o efeito de ninhos artificiais no crescimento das crias e no sucesso do abandono do ninho. Em Outubro de 2017, no ilhéu Raso foram translocadas 10 crias bem desenvolvidas (com dois meses) de ninhos naturais para ninhos artificiais. As crias foram alimentadas durante a noite e o desenvolvimento destas comparado com 10 crias de ninhos naturais. Não houve diferenças entre os grupos nas curvas de crescimento das crias nem no sucesso de voo, que foi de 100% para ambos. Os resultados demostraram que o peso diminuiu e o comprimento da asa aumentou em ambos os grupos, para que pudessem atingir a medida ideal para voar. Os resultados deste estudo contribuirão para a restauração da vida selvagem que antes existia em Santa Luzia de forma a melhorar o estatuto de conservação desta espécie.

Palavras-chave: crias de cagarra, dieta, ilhas, ninhos artificiais, sucesso de voo

ABSTRACT

The translocation of chicks is a methodology used to increase the probability of recolonization of an area where a species once nested, as is the case of the endemic Cabo Verde shearwater *Calonectris edwardsii* that occurred on the island of Santa Luzia. For this translocation to be successful, it is important to first verify its applicability. Thus, this study aimed to verify the effect of artificial nests on the growth of the young and their fledging success. In October 2017, 10 well-developed chicks (two months old) were translated from natural nests to artificial nests on Raso Islet. The chicks were fed during the night and their development compared with 10 natural nestlings. There were no differences between groups in the growth curves of the offspring or in the flight success, which was 100% for both. The results showed that the weight decreased and the wing length increased in both groups, so that they could reach the ideal measurement for flying. In this way, the results of this study will contribute to the restoration of wildlife that previously existed on Santa Luzia, in order to improve the conservation status of this species.

Keywords: artificial nests, diet, islands, fledging success, shearwater chicks

INTRODUCTION

Seabird populations are declining worldwide and, in part, due to threats they face on land (Hazevoet 1994). Predation by invasive animals introduced by humans and human capture are the main threats to seabirds in their nesting areas (Semedo *et al.* 2020). These threats have already caused local extinctions of some species of seabirds (Lopes *et al*. 2015). Once the threats that caused the decline or local extinction of a seabird population have been eliminated or reduced to negligible levels, methodologies can be used to help in the re-colonization of these areas (Geraldes *et al.* 2016). One of these methodologies is the translocation of seabird hatchlings from a reproduction area to the site where they were extinct. This procedure, defined by the movement of living organisms from one area to another mediated by humans, is complex and delicate. Knowledge of the biology of the species to be translated is essential, as well as its ecology.

Translocation, as a method of conservation, is undoubtedly an important tool, provided that certain aspects are taken into account, such as the intended objectives, choice of the adequate site, adequate transport of animals, efficiency in monitoring, feeding, possible threats that the species may face, among others. In other words, very careful planning is required for a successful translocation. Some studies have shown that the provision of artificial nests can increase knowledge about the reproductive biology of species that nest in cavities and may become a tool for their conservation (Robertson & Rendell 1990).

The Nature Reserve of Santa Luzia is the largest natural reserve in the country and comprises the uninhabited island of Santa Luzia (35 Km^2) and Branco (2.78 Km^2) and Raso (5.76 Km^2) islets (Freitas *et al.* 2015). After Cabo Verde colonization, whalers used the islands regularly, introducing mice and rats (Lopes *et al*. 2015). Later the establishment of shepherds with their domestic animals (goats and cats) would lead to the introduction of more mammal species on the island of Santa Luzia (Lopes *et al*. 2015). This has caused the disappearance of the shearwater, as a result of predation on chicks and adults, and other seabirds, such as *Pelagodroma marina* (Hazevoet 1994). At present, no seabirds are known to breed on Santa Luzia, although the presence of feathers found in crevices and of a possible nesting bird strongly point to the possibility of Cabo Verde storm petrels *Hydrobates jabejabe* attempting to breed at the cliffs (Oliveira *et al*. 2013, Geraldes *et al*. 2016, Semedo *et al.* 2020).

Santa Luzia has significant potential for seabird restoration by translocations once predators are removed because it is uninhabited, still has suitable habitats for their nesting and there are large colonies in the nearby islets (Hazevoet 2015). One of the main objectives of the local NGO Biosfera 1 is to restore the endemic species that existed on Santa Luzia, some of these dangerously isolated in the two islets (e. g. Raso lark *Alauda razae*), to improve their conservation status through their reintroduction (Geraldes *et al.* 2016). So, an extradition program of introduced predators has been carried out.

The Cabo Verde shearwater, *Calonectris edwardsii* (Oustalet, 1883) is an endemic species of Cabo Verde, classified as Near Threatened in the International Union for Conservation of Nature (IUCN) Red List (Birdlife International 2018), which uses different areas of the Atlantic Ocean during the non-breeding period (Hazevoet 1995). The species is classified as Endangered at the national level and also on Raso and Branco islets (Hazevoet 1996). Adults reach the breeding colonies during March (Hazevoet 2015). The laying of the single egg occurs in May and hatching occurs in July (Hazevoet 2015). The chicks are fed by both progenitors, leaving before sunrise, for the sea in search of food, returning to the nest after sunset (Navarro 2007). The chick remains in the nest, alone or in the company of a parent until the fledging time, between late October and early November (Murphy 1924, Hazevoet 1995). Similarly to other Procellariiformes, Cabo Verde shearwater has a high reproductive output, however, they are unable to replace an egg in case of losing it or the chick, resulting in failure of that reproductive season. Usually, the species nests in holes on the ground or rock cavities that can be very shallow in accessible or inaccessible coastal areas, such as cliffs (Hazevoet 2015). Cabo Verde shearwaters on Raso islet feed on the most abundant commercial fish species, such as *Sardinella maderensis*, bigeye scad *Selar crumenophthalmus* or scad *Decapterus sp* species, and non-commercial prey, like keelted needlefish *Platybelone argalus lovii* or squid *Loligo* sp. (Rodrigues 2014). Knowledge of the diet of the species is important for a successful translocation of the offspring, since translocated chicks need to be artificially fed. The main objective of this study was to verify the effect of the artificial nests on the growth of chicks during their development and abandonment of the nests.

MATERIAL AND METHODS

The Raso Islet (16°36’40.63”N, 24°35’15.81”W) is part of the Marine Reserve of Santa Luzia (Fig. 1) and it was declared as an Integral Reserve (Decreto-Lei Nº3/2003). It has an arid climate with a highly notable biological diversity (Freitas *et al.* 2015). Home to one of the largest populations of the Cabo Verde shearwater, Raso Islet is of great importance for the species. In 2018, a census was conducted on Raso Islet, and 6544 breeding pairs of Cabo Verde shearwaters were estimated (Paiva *et al.* 2015). The presence of important populations of other species, such as brown booby *Sula leucogaster*, red-billed tropicbird *Phaethon aethereus* and the endemic Raso lark *Alauda razae* increases the biological importance of the islet even more (Hazevoet 1995).

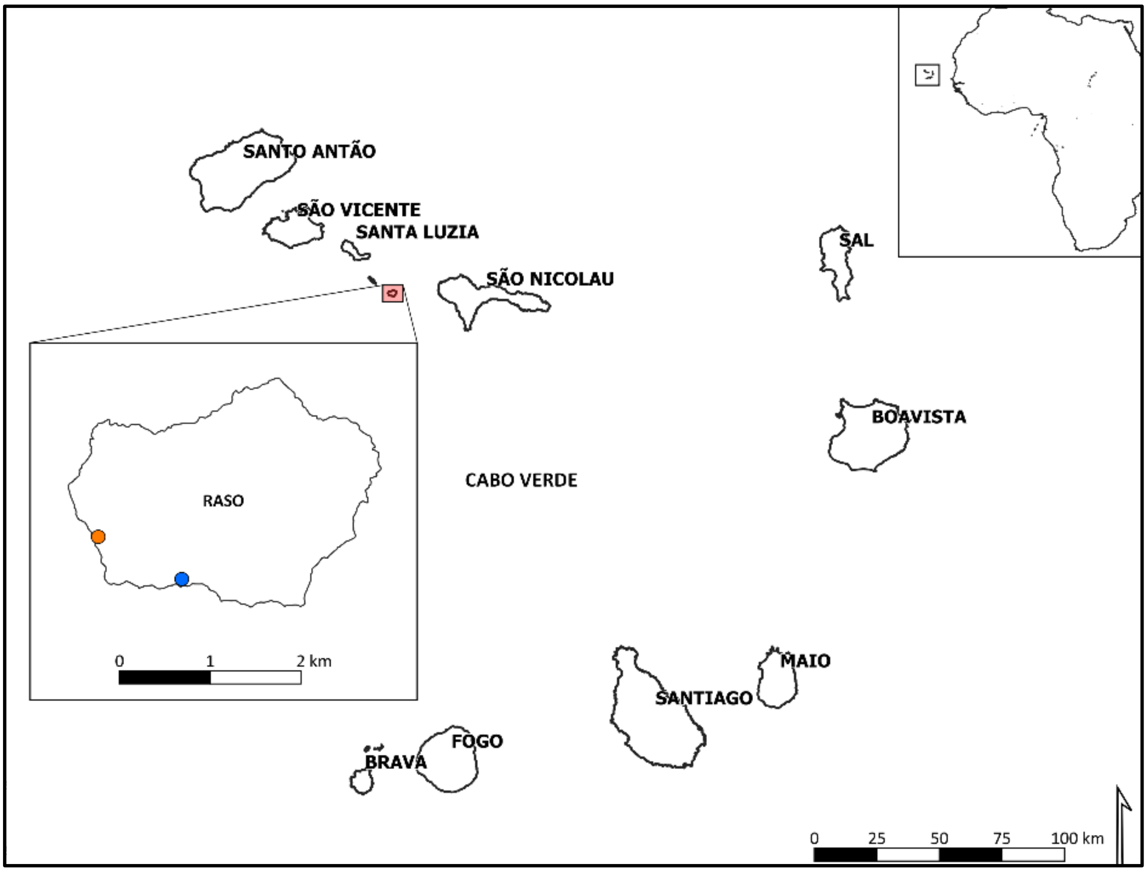

Fig. 1. Study site. Geographic location of Cabo Verde, Raso Islet in the Cabo Verde Archipelago, and the sites from where the seabirds were translocated (blue dot), and the artificial nets were set (orange dot).

In October 2017, 10 artificial nests were built on the southwest of Raso islet (Fig. 2). The nests were constructed with Bioflex cement and large stones, finishing with pebbles in front of the nest, to look as natural as possible. The site for the artificial nests was chosen and located in an area that is frequently used by shearwaters during the night. Subsequently, the nests were occupied by 10 chicks from the south of Raso. The translocated chicks were approximately two months old and from parents with successful reproduction in the past. The chicks, with indeterminate sexes, were randomly selected and were all well developed to facilitate the work (check raw data here: https://figshare.com/s/32624e8c376522cb629e), since during this period they are less frequently fed as they need to lose weight in preparation for fledging (Hazevoet 1995). The chicks were transported in October 04 in dark bags to avoid stress. Chicks, with initial weight between 470 to 710 grams, were hand-fed every day at night 100 g portions of fresh white seabream *Diplodus lineatus*, mackerel scad *Decapturus macarellus*, bigeye scad *Selar crumenophthalmus*, Cabo Verde mullet *Chelon bispinosus*, and one species of mollusc, the Atlantic white-spotted octopus *Callistoctopus macropus*.

Fig. 2. Construction of artificial nests for Cabo Verde shearwaters *Calonectris edwardsii* in the southwest of Raso Islet, Cabo Verde (photos by K. Delgado).

Additionally, ten chicks were randomly selected from a southwest population on Raso Islet to serve as controls. Both translocated and control chicks were monitored three times per week in the mornings. During this monitoring, biometric data was collected – length of wings, and weight. The wing measurement was taken using a ruler (± 0.5 mm) and weight using a spring scale (± 10 g). The chicks were always measured and weighed by the same person. These data were collected until the chicks were able to fly (mid of November). The information gathered was compiled into a database made available on Figshare (https://figshare.com/s/32624e8c376522cb629e). Dynamic tables were built to allow data analysis of the mean values per week of both variables. To compare the values of the chicks from artificial and control nests, 5 t-tests were performed between (1) the mean wing length and (2) mean weights in the translocation day, so we may say that the later differences will be due to translocation; (3) the mean maximum weights; and (4) the mean wing length and (5) weights before fledging of the two groups.

RESULTS

Of the 10 translocated shearwater chicks, all survived and fledged. The first juveniles of shearwater began to fly on the fourth week of monitoring. Regarding the mean wing lengths of the initial and final of the test between translocated and control juveniles, they did not present very different values (initial t_9= -2.19; p= 0.20; final t_9= 0.23; p= 0.40; Fig. 3). In the first few weeks, the mean wing length of the juveniles of translocated shearwater was slightly higher those of the control. However, from the fourth monitoring week, there was a slight reduction in the average wing length of translocated shearwater juveniles, which remained practically constant until the fledge of the chicks. The values of the initial and final weight (t_9= 2.39; *p*= 0.02; t_9= 2.39; *p*= 0.02) were significantly different between groups, but not the mean maximum weight before the fledge of juveniles (t_9= 0.84; *p*= 0.20; Fig. 3).

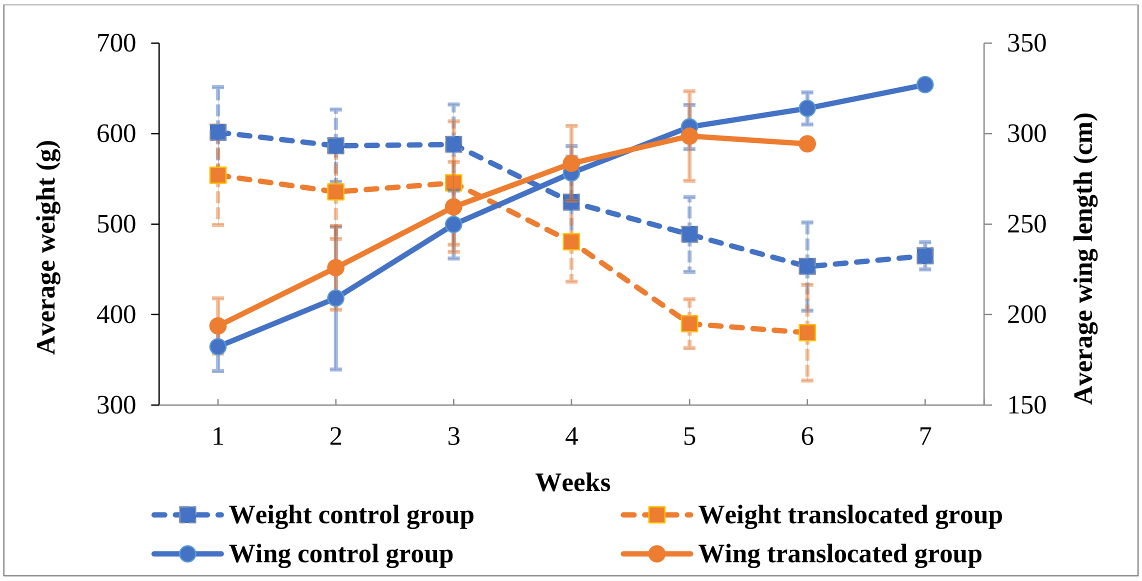

Fig. 3. Results of the artificial nest experiment. Weekly variation of the average (± standard deviation) of the weight (dashed lines) and wing length (full lines) of the 10 translocated (in orange) and the 10 control (in blue) shearwater *Calonectris edwardsii* offsprings of Raso Islet, from translocation until fledging.

DISCUSSION

The translocation test proved to be viable for future translocations of Cabo Verde shearwaters, as all 10 translocated chicks survived and fledged. The fact that the chicks were removed from their original nests and translocated to artificial nests did not affect their wing growth in comparison to the control chicks, similarly to translocations performed in other seabird island populations (Miskelly *et al.* 2009). In fact, according to Rodrigues (2014) the average wing length of the actual translocated shearwater juveniles (250.1 mm) does not differ much from the average wing length of the juveniles of the 2014 campaign (310.0 mm), also conducted on Raso Islet. However, even if the translocation is successful and all chicks fledge, it does not mean that they will nest there (Oro *et al.* 2011). Monitoring of demographic, behavioural and ecological parameters after reintroduction several years after translocation is essential to measure its success and make strategic adjustments, if necessary (Bambirra & Ribeiro 2009).

The diet based on selected prey were sufficient to guarantee the body growth of the translocated chicks, since they did not present significant differences in maximum body mass in relation to the other chicks. However, translocated chicks were significantly lighter than the controls and previously monitored chicks before fledging (Rodrigues 2014). This may be due to differences in the sex ratios of the two groups, which were unable to be determined. This observation does not diminish the adequacy of the tested diet for translocation, as this issue may be resolved in future translocations increasing the proportions of food given to the translocated individuals or the frequency they are fed.

Both the translocated and control chick started to lose weight in the third week of monitoring. Weight loss is due to the fact that shearwaters, when still underdeveloped, present a much larger weight, but over time, they begin to lose weight in order to be able to fly to the sea (Lack 1968). Most translocated chick flew in the 6th week of monitoring, while control chick flew between the 6th and 8th week of monitoring. This may indicate that the translocated chicks could be older than the control ones, even though their wing length was similar. Therefore, weight should be also used to estimate age in the following studies.

CONCLUDING REMARKS

The juveniles of translocated shearwater all survived and flew, which leads us to believe that the method was effective, taking into account the result obtained. However, the success of this method can only be evaluated after the natural occupation of the nests by adults in the following years, as this was only a test. If occupied, we can build more nests on Santa Luzia and reintroduce this important Cabo Verde endemic species.

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Nota breve | Short note

Rare sighting of pygmy killer whales *Feresa attenuata* off São Nicolau Island, Cabo Verde

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The pygmy killer whale (PKW) *Feresa attenuata* Gray, 1874 is a small pantropical delphinid, occasionally observed in subtropical and warm temperate waters (Still *et al.* 2019). It is naturally rare throughout its range (Braulik 2018) and its ecology is still poorly known (López-Suárez *et al.* 2012). The distribution of PKW worldwide overlaps with that of the melon-headed whale (MHW) *Peponocephala electra* Gray, 1846, with which it can be easily confused because of their similar external morphology. In contrast to PKW, MHW can be relatively common in some areas of its range (Kiszka & Brownell 2019).

There are a few confirmed sightings of PKW in the Atlantic Ocean off the West African coast where many records are insufficiently documented to be considered valid (López-Suárez *et al.* 2012, Berrow *et al.* 2020). In the Cabo Verde Islands, only two previously published records are unequivocal: a mass stranding of seven individuals on the northern coast of Boavista Island in February 2012 (López-Suárez *et al.* 2012) and a live sighting of circa 30 individuals (including calves) off Fogo Island in September 2019 (Berrow *et al.* 2020). Hereafter, we report on a third, previously unpublished, record.

On 3 June 2018 at 13:30 UTC, during a catamaran cruise to Raso Islet, a group of four PKWs was opportunistically observed for 10 minutes over the continental shelf (water depth= 50 m) about 1.15 km off the coast of Barril, São Nicolau Island (16°35’01’’N, 24°24’27’’W; Fig. 1). The individuals were travelling 50–100 m in front of us at a relatively slow pace and were never seen lifting their heads very high above the surface. Based on their size and the presence of scars, we initially misidentified the four individuals as black subadult Risso’s dolphins *Grampus griseus* Cuvier, 1812. About two hours later, and as we were approaching the north-eastern coast of Raso Islet, a second group of delphinids was observed at relatively close (45–90 m) range (16°38’21.4’’N, 24°33’01.4’’W; water depth= 680 m). This time, the pod was substantially larger than the previous one, comprising an estimated 10–15 individuals, which were travelling in a more energetic manner, often lifting their heads completely clear of the water surface. A close examination of our photographs showed that this pod were all MHWs (Fig. 1).

Fig. 1. Pygmy killer (PKW) and melon-headed (MHW) whales photographed off São Nicolau Island, on 3 June 2018 (photos by V. Legrand / AGAMI). **A**) and **B**) Diagnostic features of the former compared to the latter include a more rounded forehead with thicker white/ pinkish lips extending onto the face, and a dark dorsal cape contrasting with the paler flanks, respectively. **C**) In contrast, MHW shows a relatively more pointed head shape with thinner white lips. Noteworthy here is also the difference in surfacing behaviour of both species, with MHW usually lifting the head completely above the surface, unlike PKW.

In contrast to MHW, which is frequently sighted in the vicinity of the Cabo Verde Islands (S. Berrow pers. comm.), PKW remains a rare encounter at this latitude in the North Atlantic Ocean. High quality photographic documentation of PKW is also infrequent in the literature; hence those obtained during our cruise were supplied for use in the recent Europe’s Sea Mammals (Still *et al*. 2019). In conclusion, these three confirmed records of PKW (2012, 2018, 2019) suggest that there may be a small resident population in the Cabo Verde Islands, and therefore further research should be conducted to estimate encounter rate (relative abundance) and seasonal movements.

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SOCIEDADE CABOVERDIANA DE ZOOLOGIA

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Cria da cagarra de Cabo Verde *Calonectris edwardsii* no Ilhéu Raso, 2017| Chick of Cabo Verde shearwater *Calonectris edwardsii* on Raso islet, , 2017 (fotografia de | photo by Nathalie Melo)

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