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Nota editorial

Tecnologia e biodiversidade

A tecnologia revelou-se fundamental para o avanço da humanidade e nunca tanto como agora vemos isso. Graças a uma vacina que reúne vários avanços tecnológicos, vamos poder sair mais das nossas casas e olhar a biodiversidade que nos rodeia com outros olhos. Neste número temos exemplos de como também a tecnologia nos permite ser mais eficazes e rápidos em inventariar e monitorizar a biodiversidade que estamos a perder a um ritmo alucinante.

Neste número temos, como habitualmente, três publicações, desta vez um artigo e duas notas breves. A primeira publicação, intitulada “*Registo confirmado da cavala americana Decapterus tabl no arquipélago de Cabo Verde baseado em dados morfológicos e genéticos*”, mostra que o uso de novas ferramentas, neste caso o *barcoding* de ADN, aliadas às metodologias tradicionais acelera a inventariação da biodiversidade. Neste estudo valida-se a captura da cavala americana em pelo menos duas ilhas do arquipélago. Os autores demonstram ainda que os indivíduos encontrados nas águas de Cabo Verde têm afinidades com indivíduos encontrados noutras ilhas do Atlântico. No entanto, muitas questões quanto à origem desta espécie são levantadas, ficando ainda no ar se a presença esta estará relacionada com a tropicalização, mudanças climáticas e/ ou migrações transatlânticas.

A segunda publicação pergunta: “*Estará o Sula sula a reproduzir-se nas falésias da Baía do Inferno, ilha de Santiago, Cabo Verde?*”. Esta nota breve mostra, mais uma vez, como o uso de novas ferramentas, drones neste caso, são úteis para potenciar a monitorização da biodiversidade. Esta nova ferramenta é particularmente útil em lugares pouco

acessíveis, como falésias e ilhéus, e demonstrou ser capaz de registar as primeiras provas de tentativas de reprodução do alcatraz de patas vermelhas no arquipélago. Estes resultados revelam-se promissores, apontando as vantagens desta metodologia ser aplicada noutros lugares remotos do país e a outros grupos taxonómicos pouco conhecidos.

A terceira e última publicação, é uma nota breve que descreve uma associação simbiótica entre um molusco, nomeadamente o leque-do-mar, e um camarão. “*Protegendo uma espécie hospedeira: caso de estudo do Pontonia pinnophylax (Decapoda, Palaemonidae) nos leques-do-mar Pinna rudis (Bivalvia: Pinnidae)*” relata e descreve a presença destes camarões da espécie *P. pinnophylax* no interior destes moluscos, protegidos por leis internacionais, na ilha de São Vicente. A interdependência destas espécies vem acentuar a necessidade de implementar uma visão holística para a efectiva protecção das espécies.

Resta assim desejar que estejamos mais conscientes de que todas as formas de vida estão interligadas e que temos que usar toda a tecnologia que está ao nosso alcance para as melhor estudar, entender e proteger.

Doutora Raquel Vasconcelos
Editora-chefe da *Zoologia Caboverdiana*

Editorial note

Technology and biodiversity

Technology has proven to be fundamental to the advancement of humankind and now, more than ever, we do realize it. Thanks to a vaccine that brings together several technological advances, we will be able to leave our homes steadily and look at the biodiversity that surrounds us with fresh eyes. In this issue, we have examples of how technology also allows us to more effectively and quickly catalogue and monitor the biodiversity that we are losing at an astonishing rate.

In this issue we have, as usual, three publications, this time an article and two short notes. The first publication, entitled "*Confirmed record of the roughear scad Decapterus tabl in the Cabo Verde Archipelago based on morphological and genetic data*", shows that the use of new tools, in this case DNA barcoding, combined with traditional methodologies accelerates the inventory of biodiversity. This study validates the capture of the roughear scad in at least two islands of the archipelago. The authors further demonstrate that individuals found in Cabo Verde waters have affinities with individuals found in other Atlantic islands. However, many questions regarding the origin of this species are raised, and it is on the air whether its presence is related to tropicalization, climate change and/ or transatlantic migrations.

The second publication asks: "*Is Sula sula breeding in the cliffs of Baía do Inferno, Santiago Island, Cabo Verde?*". This short note shows, once again, how the use of new tools, drones in this case, are useful to enhance biodiversity monitoring. This new tool is particularly useful in inaccessible sites, such as cliffs and islets, and has shown to be

able to record the first evidences of breeding attempts of the red-footed booby in the archipelago. These results are promising, showing the advantages for this methodology to be applied in other remote places in the country and to other little-known taxonomic groups.

The third and final publication is a short note describing a symbiotic association between a mollusk, namely the rough pen shell, and a shrimp. "*Protecting a host species: a case study of Pontonia pinnophylax (Decapoda, Palaemonidae) in the rough pen shell Pinna rudis (Bivalvia: Pinnidae)*" reports and details the presence of shrimps of the species *P. pinnophylax* inside these molluscs, protected by international law, on the island of São Vicente. The interdependence of these species emphasizes the need to implement a holistic plan for the effective protection of species.

Therefore, I wish that we are more aware that all life forms are interconnected and that we have to use all the technology that is at our reach to better study, understand and protect them.

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



Artigo original | Original article

Confirmed record of the roughear scad *Decapterus tabl* in the Cabo Verde Archipelago based on morphological and genetic data

Evandro P. Lopes^{1,2,*}, Vanda Monteiro³, Albertino Martins⁴, Rui Coelho^{5,6},
Rui Freitas¹, Tina Blancke⁷ & Reinhold Hanel⁷

¹ ISECMAR/UTA, Instituto de Engenharias e Ciências do Mar, Universidade Técnica do Atlântico,
CP 163, Mindelo, São Vicente, Cabo Verde

² CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado,
Universidade do Porto, Campus Agrário de Vairão, 4485-661 Vairão, Portugal

³ IMAR, Instituto do Mar, CP 132, Mindelo, São Vicente, Cabo Verde

⁴ DGRM, Direcção Geral dos Recursos Marinhos, Campus do Mar, Mindelo, São Vicente, Cabo Verde

⁵ IPMA, Instituto Português do Mar e da Atmosfera, 8700-305 Olhão, Portugal

⁶ CCMAR, Centro de Ciências do Mar do Algarve, Universidade do Algarve, Campus de Gambelas,
8005-139 Faro, Portugal

⁷ Thünen Institute of Fisheries Ecology, 27572 Bremerhaven, Germany

* Corresponding author e-mail: elopes@uta.cv

RESUMO

A ocorrência de *Decapterus tabl* é confirmada pela primeira vez no arquipélago de Cabo Verde. vários espécimes capturados nos anos 2015 e 2020 demonstraram serem muito diferentes de *Decapterus macarellus* e *Decapterus punctatus*, ambas as espécies já assinaladas para as águas de Cabo Verde, com base em dados morfométricos, merísticos e moleculares. Morfologicamente, esta cavala atinge maior tamanho do que as congéneres, possui barbatana caudal avermelhada, margem serrilhada na membrana do opérculo, 10 a 12 branquispinhas (primeiro arco branquial) na porção superior e 30 a 33 na inferior (incluindo rudimentares). O *barcoding* genético baseado no citocromo oxidase I mitocondrial corrobora os dados merísticos e morfométricos, validando a presença local da chamada “cavala americana” no arquipélago de Cabo Verde.

Palavras-chave: Atlântico Nordeste, Carangidae, *Decapterus* spp., mtDNA

ABSTRACT

The occurrence of *Decapterus tabl* is confirmed for the first time for the Cabo Verde Archipelago. Several specimens from fisheries catches in the years 2015 and 2020 proved to differ unambiguously from *Decapterus macarellus* and *Decapterus punctatus*, both species already reported from Cabo Verde waters, based on morphometric, meristic and molecular data. Morphologically, the rougher scad reaches larger sizes than its congeners, presents reddish caudal fin, serrated margin on the operculum membrane, 10 to 12 gill rakers in the upper limbs and 30 to 33 gill rakers in lower limbs (including rudiments). A genetic barcoding analysis based on mitochondrial cytochrome oxidase I corroborates the meristic and morphometric data, validating the presence of the locally called ‘*cavala americana*’ in the Cabo Verde Archipelago.

Keywords: Carangidae, *Decapterus* spp., mtDNA, Northeastern Atlantic

INTRODUCTION

The carangid genus *Decapterus* Bleeker, 1851 is well represented in the pelagic zone of central Eastern Atlantic shelves, with a northern distribution limit of some of the northern species around the Strait of Gibraltar and the southern species reaching South African coasts. Of the ten species listed in this genus, four occur along the West African coast: *Decapterus macarellus* (Cuvier, 1833), *Decapterus punctatus* (Cuvier, 1829), *Decapterus muroadsi* (Temminck & Schlegel, 1844), and *Decapterus tabl* Berry, 1968 (Smith-Vaniz 2016).

To date, only two species have been reported for the Cabo Verde Archipelago: the mackerel scad *D. macarellus* and the round scad *D. punctatus* (Reiner 2005, Wirtz *et al.* 2013, Hanel & John 2015). In the southeastern Atlantic, the amberstripe scad *D. muroadsi* and the rougher scad *D. tabl* are known only from Saint Helena surroundings (Smith-Vaniz *et al.* 1990, Kimura *et al.* 2013, Smith-Vaniz, 2016, Wirtz *et al.* 2017). In the Northeastern Atlantic, Bañón *et al.* (2019) only recently reported *D. tabl* for Madeira.

Decapterus tabl is an epipelagic oceanic and coastal (reef-associated) circumtropical species (Berry & Smith-Vaniz 1978). On the

global scale, the species has been reported for Bermuda and from North Carolina to Venezuela in the Western Atlantic Ocean, for the Indian Ocean, and the Indo-West Pacific eastwards to Hawaii (Berry 1968, Kim & Koh 1994, Kimura *et al.* 2013, Smith-Vaniz 2016). Adult specimens use the whole water column from near the surface and mid-water to near the bottom. The recorded maximum total length (TL) is 50 cm and maximum weight 560 g (Berry & Smith-Vaniz 1978, Smith-Vaniz 1986), while the most commonly observed size is around 25–35 cm TL (Cervigón *et al.* 1992, Smith-Vaniz 2016). It feeds on small planktonic invertebrates, primarily copepods (Cervigón *et al.* 1992, Smith-Vaniz 2016).

The present study aims at confirming the regular occurrence of *D. tabl* in Cabo Verde based on meristic counts and molecular markers. An unambiguous differentiation of the three distinct *Decapterus* species found in the archipelago will facilitate accurate landing data and, therefore, better knowledge on population dynamics and stock size, ultimately leading to better scientific advice for fisheries management.

MATERIAL AND METHODS

The first specimens of *D. tabl* used in this study were collected in 2015 near Flamengo Bay off São Vicente's southern coast, standing out due to their large size and reddish caudal fin. The vessel landed several tons of scad captured at 50 m deep. One specimen was brought to Instituto do Mar (IMAR), former Instituto Nacional de Desenvolvimento das Pescas at Mindelo, São Vicente, for photo recording. It was not possible to get biometric or molecular data for this specimen because it was lost. In addition, four *Decapterus* specimens (KV293a, KV294a, KV302a, KV303a), one with reddish caudal fin, were photographed and a muscle tissue sample collected at São Vicente's fish market on May 18, 2015 (Fig 1). Tissues were deposited in Thünen Institute, Germany, and used to extract DNA for molecular identification.

In February 2020, three additional specimens were collected at São Nicolau's fish market for morphometric characterization (Fig 1). Muscle tissue samples were deposited in the newly established biodiversity reference collection at the 'Universidade Técnica do Atlântico' at Mindelo, Cabo Verde (UCV00341–UCV00343).

Biometric measurements of these three specimens were performed with a calliper and a 50 cm length millimeter ruler. All specimens were sexed and photographed. Molecular identification of these specimens was not possible to be performed due to logistic constraints caused by the COVID-19 pandemics.

All photographs were deposited in MorphoBank (M740012–M740018; M740101–M740102; username: P3974). The meristic characters and body proportions of the specimens were compared with the metrics data retrieved from Berry (1968), Kim & Koh (1994) and Kimura (2013). Counts and measurements generally followed Hubbs & Lagler (1958) except for body depth, which was measured from the origin of the first dorsal fin (D1) to the pelvic fin in sagittal

plane (P2) and from the second dorsal fin (D2) to the first spine of the anal fin (A1). All data were compared primarily to the three Northeastern Atlantic species of *Decapterus*.

DNA extraction from samples KV293a, KV294a, KV302a and KV303a was conducted using Invisorb Spin Tissue Mini Kit (Stratec, Birkenfeld, Germany). Four fragments of approximately 650 base pairs (bp) of the cytochrome oxidase I (COI) gene were amplified using Ivanova *et al.* (2007) – Ward *et al.* (2005) cocktail primers, modified with M13 sequencing sites: VF2_t1_M13 (5'-TGT-AAA-ACG-ACG-GCC-AGT-CAA-CC A-CCA-CAA-AGA-CAT-TGG-CAC-3'), FishF2_t1_M13 (5'-TGT-AAA-ACG-ACG-GCC-AGT-CGA-CTA-ATC-ATA-AAG-AT A-TCG-GCA-C-3'), FishR2_t1_M13 (5'-CAG-GAA-ACA-GCT-ATG-ACA-CTT-CA G-GGT-GAC-CGA-AGA-ATC-AGA-A-3'), and FR1d_t1_M13 (5'-CAG-GAA-ACA-GCT-ATG-ACA-CCT-CAG-GGT-GTC-CG A-ARA-AYC-ARA-A-3').

PCR reactions were performed using Phusion High-Fidelity PCR Master Mix with HF Buffer for KV293 & KV294 samples and Q5 High-Fidelity 2X Master Mix for KV302 & KV303. The reactions were performed in a thermocycler, in a total volume of 20 µL/reaction, including 3 µL of genomic DNA, 1X PCR Master Mix and 0.25 µM of each primer. The cycling conditions started with an initial denaturation of 98°C for 30 s, followed by 32 cycles of 98°C for 10 s, 53°C for 30 s, 72°C for 20 s and a final extension at 72°C for 8 min. For quality check, 5 µL of each PCR product were visualized in agarose gel 1% stained with SERVA DNA Stain Clear G and observed in a transilluminator under UV light.

Samples were sequenced at GATC Services Eurofins Genomics (Ebersberg, Germany) using primers designed by Messing (1983): M13F(-21) (5'-TGT-AAA-ACG-ACG-GCC-AGT-3') and M13R(-27) (5'-CAG-GAA-ACA-GCT-ATG-AC-3').



Fig. 1. The five specimens of the roughear scad *Decapterus tabl* collected in Cabo Verde. **A)** Specimen caught at Flamengo Bay, off the southern São Vicente coast (photo by A. Martins). **B)** Specimen photographed from São Vicente's fish market on May 18 2015 (KV302a; photo by R. Hanel). **C)** Specimens collected at São Nicolau's fish market (from top to bottom: UCV00341 to UCV00343; photo by E. Lopes).

Sequences were assembled with CodonCode Aligner version 9.0 (www.codoncode.com/aligner/index.htm) and compared with available sequences in GenBank to taxonomically identify the specimens. The translation of mitochondrial genes was deduced using the mtDNA genetic code of vertebrates in Unipro UGENE version 1.29 (Okonechnikov et al. 2012) allowing to inspect the existence of stop codons and the

presence of pseudogenes. The global alignment was done using ClustalW algorithm present in BioEdit v.7.0.5.3 (Hall 1999). A total of 36 COI sequences with 648 bp of nine *Decapterus* species deposited in GenBank were included in the phylogenetic analyses together with four new sequences and two outgroup sequences of *Selar crumenophthalmus* (Bloch, 1793) (Table 1).

Table 1. List of samples included in the genetic analyses. Their code and taxonomic identification are given, as well as their distribution range, climatic zone, location, and GenBank accession number.

Species	Distribution	Climatic zone	Location	GenBank
<i>Decapterus sp.</i> (KV303a)	–	–	São Vicente, Cabo Verde	MT435950
<i>Decapterus sp.</i> (KV293a)	–	–	São Vicente, Cabo Verde	MT435951
<i>Decapterus sp.</i> (KV294a)	–	–	São Vicente, Cabo Verde	MT435952
<i>Decapterus sp.</i> (KV302a)	–	–	São Vicente, Cabo Verde	MT435953
<i>Decapterus akaadsi</i>	Western Pacific	Subtropical	China Sea	EF607334
			China Sea	EF607333
			South Japan	JF952716
<i>Decapterus kurroides</i>	Indo-West Pacific	Deep-water	Indonesia	JN312966
			Indonesia	HQ564303
			Indonesia	HQ564304
<i>Decapterus macarellus</i>	All oceans	Subtropical	Malaysia	KY570732
			Malaysia	KY570733
			Madeira Islands	MH980014
			Indonesia	HQ564302
<i>Decapterus macrosoma</i>	Indo-Pacific and Southeast Atlantic	Tropical	Indonesia	HQ564442
			Indonesia	HQ564377
			Panama	MF956639
<i>Decapterus maruadsi</i>	Indo-Pacific and Southeast Atlantic	Tropical	Malaysia	KY570749
			Malaysia	KY570751
			California	HQ010055
<i>Decapterus punctatus</i>	Atlantic	Subtropical	Northwest Atlantic, USA	KT883653
			Guatemala	KR086824
			North Carolina, USA	MH378676
			México	GU224777
<i>Decapterus russelli</i>	Indo-West Pacific	Tropical	South Africa, KwaZulu	JF493352
			Malaysia, Kuala Kedah	KY570767
			Malaysia, Kuala Kedah	KY570768
<i>Decapterus tabl</i>	Pacific Ocean, Western and South Atlantic	Subtropical	Portugal, Madeira Islands	MH980015
			Portugal, Madeira Islands	MH980016
			Portugal, Madeira Islands	MH980017
			China, South China Sea	KY371432
			China, South China Sea	KY371433
			China, South China Sea	KY371434
<i>Selar crumenophthalmus</i>	Circumtropical	Subtropical	China Sea	MH638715
			China Sea	MH638727

PartitionFinder v2.1.1 (Lanfear *et al.* 2012) was used to determine the best-fit partitioning schemes and models of molecular evolution to each dataset, according to Akaike's Information Criterion (Akaike 1973). The following models of molecular evolution were applied to COI partitions: GTR+G (1st partition), GTR+I (2nd partition), F81+I (3rd partition). Maximum likelihood (ML) and Bayesian inference (BI) methods were used to reconstruct *Decapterus* phylogeny. For BI analyses, performed in MrBayes v3.2.6

(Ronquist *et al.* 2012), settings included five million generations, sampling every 1000 generations, and discarding the first 25% generations as burn-in. The convergence of parameter values was assessed using Tracer v1.7 (Rambaut *et al.* 2018), excluding an initial 10% for each run. All parameter estimates for each run showed ESS values >100. A final Bayesian majority-rule consensus tree was obtained for each data set. For ML RAXML v8.1.16 (Stamatakis 2006) with the rapid hill-climbing algorithm and

10,000 bootstrap pseudoreplicates was used. The consensus trees inferred for each method were improved using FigTree v1.4.3 (<http://tree.bio.ed.ac.uk/software/figtree/>).

To identify the relationships among *D. tabl* specimens used in the present study, a non-

rooted network of haplotypes based on the 95% parsimony method was built in TCS1.21 (Clement *et al.* 2000), with deletions treated as a fifth state. The final manipulation was performed in tcsBU (Santos *et al.* 2016).

RESULTS

The macroscopic analysis of the three scad specimens collected on São Nicolau and two specimens previously collected on São Vicente showed a very elongated, almost rounded body, metallic blue dorsally, silver and whitish ventrally (Fig. 1), and moderately large eye with well-developed adipose eyelid, completely covering the eyes (Fig. 2). Even though the rougher scad shares characters with the mackerel scad, some morphological

features make a differentiation relatively simple, including the presence of reddish caudal fin, edges of dorsal, red anal and pectoral fins, white muscle tissue significantly darker and a little firmer, more rounded eyes, and overall lighter external colouration. Also, 30 gill rakers on the lower limb and serrated opercular margin pointed to the rougher scad *Decapterus tabl* (Fig. 2).

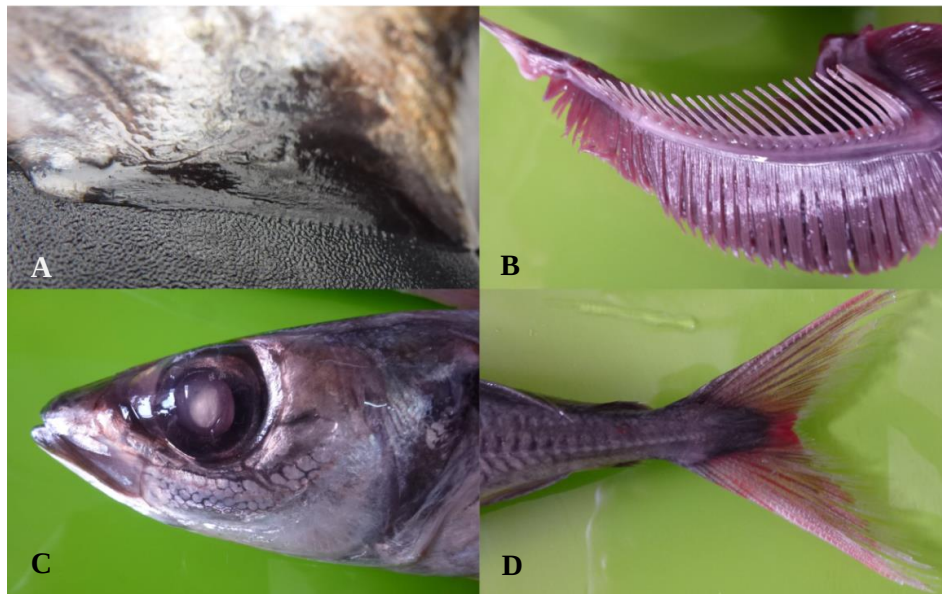


Fig. 2. Diagnostic characters of *D. tabl* from specimens acquired at the fish markets of São Nicolau, Cabo Verde (photos by E. Lopes; Morphobank M740012–M740018; M740101–M740102). **A)** Serrated margin of the opercular membrane, **B)** 30 lower gill rakers, **C)** posterior margin of the head straight, and **D)** reddish caudal fin.

In the comparison among the three species present in Cabo Verde, it was clear that the body proportions of the two females and one male *Decapterus* collected on São Nicolau, and the one collected on São Vicente, matched to *D. tabl* (Table 2). These data were

in agreement with the size and weight ranges, body proportions, and gill rakers, second anal fin, lateral line scutes counts and colour reported for this species (Berry 1968, Berry & Smith-Vaniz 1978, Kimura *et al.* 2013, Wirtz *et al.* 2017).

Table 2. Number of specimens, measurements and counts of *Decapterus tabl* collected on São Nicolau (SN) and São Vicente (SV), Cabo Verde, compared with data from Kim & Koh (1994) for Korea, Kimura *et al.* (2013) for Caribbean Sea (CS) and Berry (1968) for Western Atlantic (WA) and St. Helena (SH) and close-related species. Measurements are presented in percentage of standard length. D1 and D2 stand for first and second portion of dorsal fin, respectively, P2 for pelvic fin in sagittal plane, and A1 for first spine of anal fin. True spines were counted and are reported in uppercase Roman numerals and soft rays in Arabic numerals.

Variables	Present study		Kim & Koh (1994)	Kimura (2013)	Berry (1968)			
	<i>D. tabl</i>		<i>D. tabl</i>	<i>D. tabl</i>	<i>D. tabl</i>		<i>D. punctatus</i>	<i>D. macarellus</i>
	SN	SV	Korea	CS	WA	SH		
Number of specimens	3	1	1	8	50	2	–	–
Standard length (mm)	313–348	–	180	156–203	156–199	351–360	140–183	145–256
Total length	118–118	–	115	–	113–115	114	116–117	115
Fork length	106–108	–	106	–	104–106	106	106–108	106–107
Head length	29.0–30.3	–	27.6	27.4–30.5	27.5–29.0	28.8–30.0	25.5–27.5	25.2–26.8
Eye diameter	6.7–7.4	–	6.8	7.1	6.5–7.4	7.1–8.5	7.1–7.9	5.9–6.9
Snout length	10.1–10.6	–	10.0	9.8	8.3–10.4	9.4–10.7	7.3–9.1	8.3–9.4
Postorbital head length	14.7–14.7	–	16.7	12.4	11.8–13.0	11.4–11.9	10.2–12.3	10.5–11.4
Upper jaw length	9.4–9.9	–	9.2	9.6	9.2–9.9	10.0–10.3	8.3–8.6	7.8–8.5
Maxillary depth	2.7–3.3	–	3.1	–	2.8–3.4	3.1–3.2	2.9–3.2	2.7–3.1
Body depth D1–P2	18.5–18.7	–	9.2	–	17.0–20.2	20.1–20.2	18.8–22.0	17.4–19.2
Body depth D2–A1	19.4–20.7	–	24.1	–	16.5–20.0	19.8–20.0	19.5–23.1	17.3–18.9
Maximum body depth	19.8–21.8	–	22.8	16.6–23.0	16.7–19.8	19.5–19.7	18.8–23.0	16.1–18.9
Pectoral-fin length	20.1–21.0	–	24.3	17.8–21.5	16.4–18.1	18.8–19.4	18.2–23.5	15.3–17.5
Pelvic-fin length	11.0–11.8	–	13.0	10.8–13.0	10.5–12.1	11.4–12.9	11.0–13.0	9.9–12.1
Longest dorsal spine	11.6–15.1	–	14.9	10.7–15.0	12.4–13.9	13.2–13.8	12.4–15.6	10.3–13.6
Longest dorsal soft ray	9.4–12.2	–	10.4	–	10.2–11.2	10.9–11.4	11.5–12.4	8.9–9.5
Longest anal spine	2.4–2.7	–	1.3	2.0–3.9	2.9–3.7	2.9–2.9	4.2–4.6	3.2–3.8
Longest anal soft ray	9.0–10.5	–	–	–	8.8–9.5	9.5–9.9	10.1–11.3	7.5–8.7
Lateral-line ratio	0.7	–	–	–	0.6–0.9	0.7–0.8	0.9–1.2	0.8–1.0
Dorsal fin	VIII, I+33	–	VIII, I+32	–, 29–32	VIII, I–29–34	–	VIII, I+29–34	VIII, I+31–37
Anal fin	II+I+26	–	II+I+26	–, 23–26	II+I+24–27	–	II+I+26–30	II+I+27–31
Pectoral fin	21	–	21	–, 20–21	20–22	–	18–20	21–23
Pelvic fin	I+5	–	I+5	I+5	I+5	–	I+5	I+5
Upper gill rakers	10	–	11	9–10	10–12	–	11–13	9–13
Lower gill rakers	30	30	31	30–32	30–33	–	32–37	31–39
Branchiostegal rays	7	–	7	–	7	–	7	7
Lateral-line scutes	36–38	–	37	35–38	39	–	32–56	23–32

Bayesian and Maximum Likelihood analyses showed identical results, revealing well-supported clades for most of the species described for this genus. Three *Decapterus* individuals (KV293a, KV294a, KV303a) collected at São Vicente grouped within the clade of *D. macarellus*, and one (KV302a), morphologically distinct, grouped with *D. tabl* sequences (Fig. 3A). The haplotype network

of *D. tabl* showed two distinct groups separated by several mutational steps: one belonging to the Pacific (China Sea) with two haplotypes, and another belonging to the Atlantic (Madeira and Cabo Verde Islands) with three haplotypes (Fig. 3B). The individuals from Cabo Verde shared the same haplotype with a sample from Madeira Island (Fig. 3B).

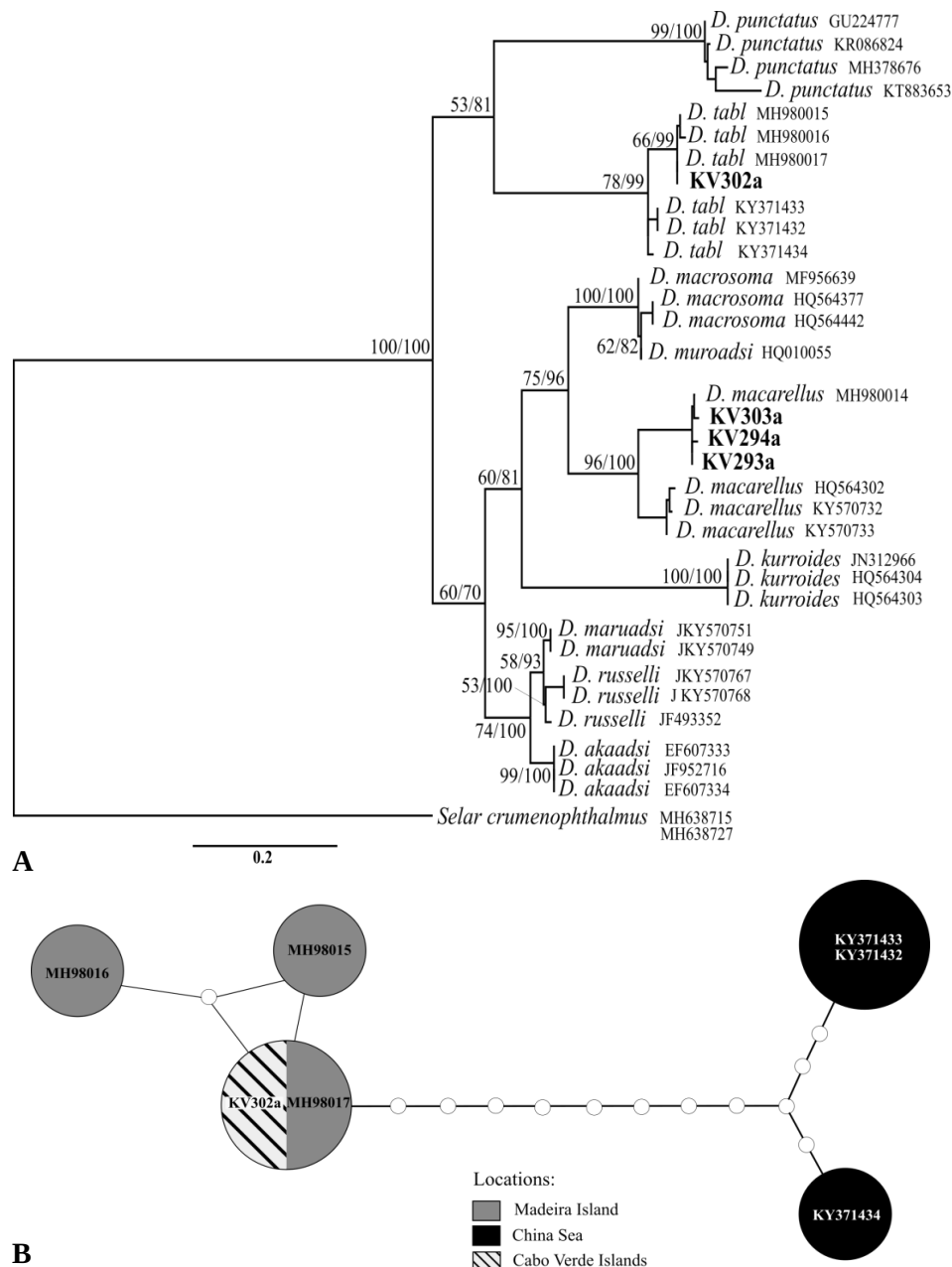


Fig.3. Phylogenetic relationships between the sequences obtained in this study and sequences retrieved from GenBank. **A)** Maximum Likelihood (ML) consensus tree for the 648 bp COI sequences of the genus *Decapterus*. Numbers at nodes are statistical support values for ML (bootstrap)/ BI (Bayesian posterior probabilities). *Decapterus* samples collected on São Vicente, Cabo Verde are shown in bold. Scale bar indicates substitutions per site. The GenBank accession codes or sample codes are also given. **B)** Haplotype networks of *D. tabl* for the COI marker. Lines represent mutational steps and circles represent haplotypes. The size of circles is proportional to the number of individuals.

DISCUSSION

The morphological characters provided in the diagnosis and the molecular data showed that the specimens found near São Nicolau and São Vicente belong to *Decapterus tabl*, a species now formally confirmed for Cabo Verde waters. The Cabo Verde Archipelago is the second northeastern Atlantic insular habitat for which the presence of the species was confirmed. Recently, Bañón *et al.* (2019) reported the occurrence of the species around Madeira, confirmed by morphological and DNA barcoding (COI) data. This new record for Cabo Verde is important, as it supports the possibility of a more widely distribution of the species in the Northeastern Atlantic, potentially from Madeira in the north and Saint Helena in the south. It is also important economically, as the species is used locally for human consumption and has increased its economic value considerably due to the decreasing of *D. macarellus* catches and landings (Santos, 2018).

Records of new and rare fish species especially around oceanic islands are often considered occasional events (Afonso *et al.* 2013). However, in the nearby Canary Islands, tropicalization processes have recently been described as important driving forces increasing fish diversity (Brito *et al.* 2017). Natural immigration mediated by climate change (Morley *et al.* 2018) is therefore also a possible explanation for recent records of *D. tabl* around Madeira and Cabo Verde islands. An alternative hypothesis

is given by Heithaus *et al.* (2008) and Baum & Worm (2009) who explained increased transatlantic migration of schools of small pelagic fish like scads and mackerels as a result of overfishing of oceanic predators (sharks and/or tunas), triggering shifts in the oceanic top-down control. However, it seems equally likely that transatlantic migration is an ocean current driven process, affecting early larval stages of fish (Rocha *et al.* 2008). The permanent occurrence of the rougher scad around Bermuda could be a steppingstone for the eastward transport of patches of larval scad with the North Atlantic gyre.

Cabo Verde has been repeatedly mentioned in the context of pan-Atlantic marine connectivity (van der Land 1993, Morri *et al.* 2000), largely due to a distinct American (mainly Caribbean) imprint, expressed by the occurrence of predominantly Western Atlantic seaweeds (Prud'homme van Reine *et al.* 2002), but also by fish species like moray eels (Muraenidae), damselfishes (Pomacentridae), wrasses (Labridae), and triggerfishes (Balistidae) (Floeter *et al.* 2008). Future phylogeographic and population genetic studies are needed to reveal the origin of this species and the establishment of a population in Cabo Verde, and the consequences of the latter for native species. New records of *D. tabl* can thus be traced back to a founding population in the southeast Atlantic and link genetic data by trans-oceanic processes.

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Nota breve | Short note

Is *Sula sula* breeding in the cliffs of Baía do Inferno, Santiago Island, Cabo Verde?

Nuno S. Loureiro^{1,*}, Ermelindo Reis², Denis Dias², Ana Veiga²

¹ Universidade do Algarve, DCTMA-FCT, Campus de Gambelas, 8005–139 Faro, Portugal

² Associação Lantuna, Praia, Cabo Verde

* Corresponding author e-mail: nlourei@ualg.pt

Keywords: seabird, Sulidae, red-footed booby, new breeding species, drone surveys

Eight seabird species breed in Cabo Verde (Semedo *et al.* 2021). Others, including the red-footed booby *Sula sula*, occur as non-breeding visitors or vagrants (Hazevoet 1995, 2014). With three main plumage morphs – white, white-tailed brown, and brown – and several intermediate morphs, *S. sula* is the most polymorphic Sulidae (Nelson 1978). The plumage colour has a genetic basis and allows the identification of their geographical origin (Baião *et al.* 2007). White and white-tailed brown morphs occur in the Atlantic, the former predominantly in the South Atlantic, and the latter in the Caribbean (Hartog 1987).

The first *S. sula* record for Cabo Verde, a white-tailed brown individual on Rombos, dates from August 1986 (Hartog 1987). Almost three decades passed before the next sighting of a white morph adult and a non-

confirmed breeding event, both on Raso (Hazevoet 2014, Moran *et al.* 2018), where nowadays about 130 individuals are present, but only between June and October (Biosfera pers. comm.). The oldest record in Baía do Inferno, Santiago Island, one white individual, dates from August 2015 (S. Martins pers. comm.).

The Important Bird and Biodiversity Area ‘Coastal cliffs between Porto Mosquito and Baía do Inferno’ hosts one of the largest brown booby *Sula leucogaster* colonies in the archipelago (BirdLife International 2021). Close to Ponta Geneanes, seabirds nest along 1.5 km, from near sea level to the 100–250 m high cliff tops (Fig. 1A). From November 2020 to April 2021, we performed 43 19-min drone (DJI Phantom 4 Pro V2.0) surveys to study booby’s population size and phenology.

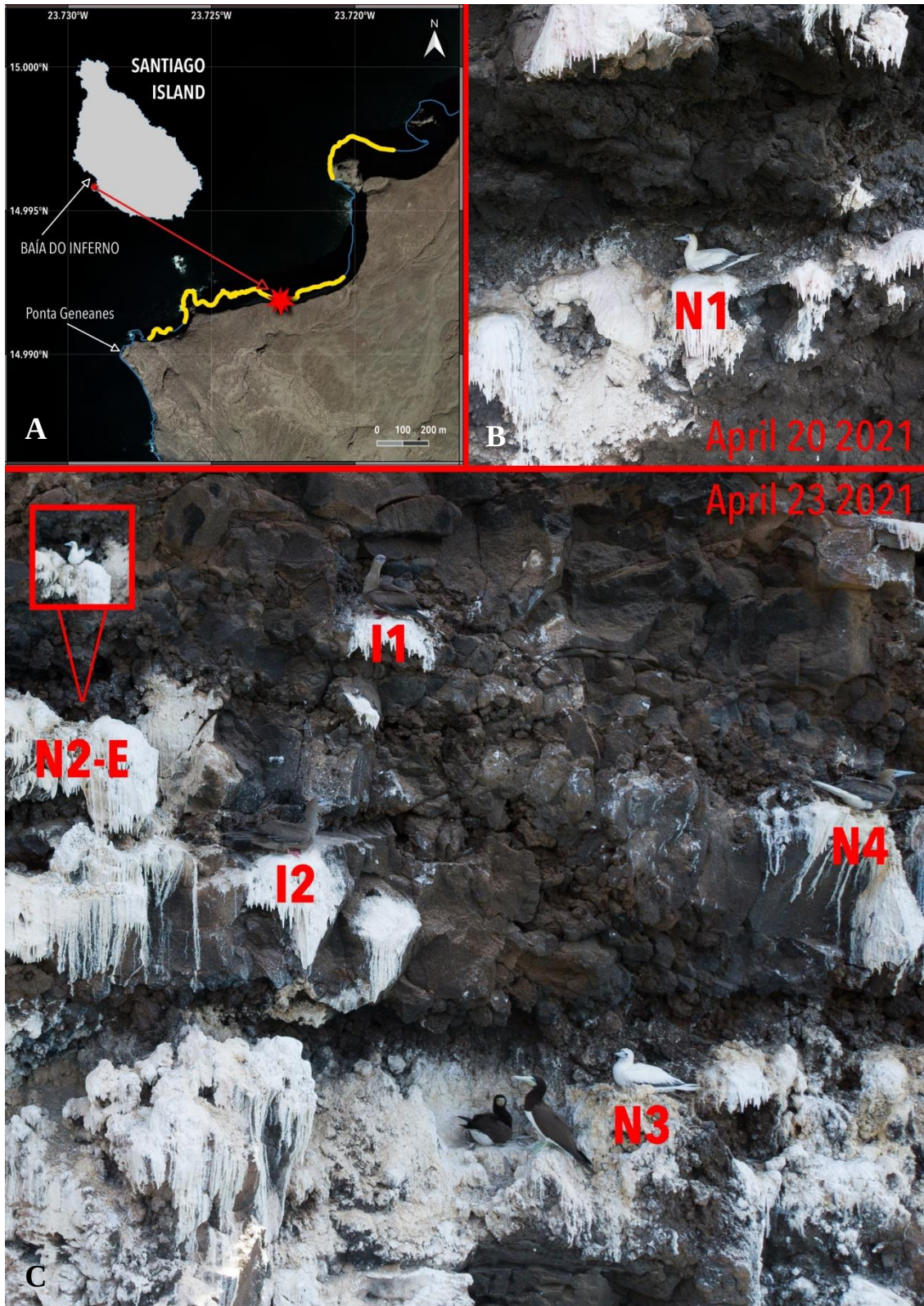


Fig. 1 Study area and records of *Sula sula* in Baía do Inferno, Santiago Island (photos by N.S. Loureiro). **A)** Drone-surveyed area. In blue the coastline, in yellow the distribution of the brown booby *Sula leucogaster* colony, and in red the site of *S. sula* records. **B)** Photograph record performed on April 20 2021. N1 marks a white morph adult *S. sula* on a nest-like structure. **C)** Photograph records performed on April 23 2021. N2-E marks an egg on a nest-like structure, with a detail of the previously taken photograph, when the white morph adult *S. sula*, identified by the red feet, which flew away was still perched on the nest. N3 and N4 mark, respectively, a white and a white-tailed brown morph adult *S. sula* nest-like structures. I1 and I2 mark two *S. sula* immatures, identified by their dark bill tips, and the predominantly brown plumage (with different tones in the breast and the belly), as there are no all-brown adults in the Caribbean and the Atlantic.

On April 20, two white morph *S. sula* adults were found perched on the cliff. One flew off, while the other remained motionless on a nest-like structure, made of plant materials, about 150 m high (Fig. 1B). On April 23, drone photographs documented: i) two white morph adults; ii) one white-tailed morph adult; iii) two immatures; iv) three nest-like structures; v) one egg (Fig. 1C). The egg was incubated by a white morph individual, which flew away during the drone scan.

These are the first confirmed records of breeding attempts of *S. sula* in Cabo Verde. Only future genetic work will clarify if

individuals were born in the South Atlantic, the Caribbean or even Cabo Verde. We were unable to determine if egg incubation or chick hatching was successful, but the long temporal occurrence pattern of about 8–10 *S. sula* in Baía do Inferno is different from the one seasonally found on Raso. We recommend future seabird surveys in Cabo Verde to increase their focus on this species, particularly on Raso and Rombos. Using drones, which proved decisive in our study, is recommended to reduce disturbance and increase detection of individuals (Vale & Scarton 2020).

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Nota breve | Short note

Protecting a host species: a case study of *Pontonia pinnophylax* (Decapoda, Palaemonidae) in rough pen shells *Pinna rudis* (Bivalvia: Pinnidae)

Evandro P. Lopes^{1, 2, 3 *}

¹ ISECMAR/UTA, Instituto de Engenharias e Ciências do Mar, Universidade Técnica do Atlântico,
CP 163, Mindelo, São Vicente, Cabo Verde

² CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado,
Universidade do Porto, Campus Agrário de Vairão, 4485–661 Vairão, Portugal

³ Faculdade de Ciências da Universidade do Porto, 4169–007 Porto, Portugal

* Corresponding author e-mail: elopes@uta.cv

Keywords: endosymbiont species, Cabo Verde, North Atlantic Ocean, shrimp – muscle association

The *Pontonia* shrimp species are well known due to their endosymbiotic association with bivalves and ascidians (Fransen 2002, Marin & Anker 2008). Three species of this genus, *Pontonia pinnophylax* (Otto, 1821), *Pontonia manningi* Fransen, 2000, and *Pontonia pilosa* Fransen, 2002, were recorded from Cabo Verde, within fixed mollusc host species of *Pinna*, *Spondylus* and *Pseudochama* (Fransen 2002, Wirtz & Debelius 2003). *Pontonia pinnophylax* is usually observed in pairs of adults, living in the mantle cavity of live *Pinna* species, feeding on mucus and food particles collected on the surfaces of their gills and epithelium (Kennedy *et al.* 2001). In the North Atlantic, the first ecological study on the symbiotic association between this shrimp

and *Pinna rudis* was documented from the Azores (Portugal), with an occupancy rate of around 57% and higher occurrence in larger bivalves (Pacheco *et al.* 2014).

The presence of *P. pinnophylax* in Cabo Verde was first recorded by Türkay (1982) in calcareous algae at Matiota bay, São Vicente. Later, Wirtz & d'Udekem-d'Acoz (2001) found one to two *Pontonia* specimens inside live *P. rudis* specimens from Santiago Island. To evaluate the occupation rate of *P. pinnophylax* inside *P. rudis* specimens, sampling was carried out in Matiota bay (16°53'22"N and 24°59'46"W). A total of 58 *P. rudis* individuals were sampled by SCUBA diving, carefully opened and released *in situ*, and the presence of *Pontonia* was recorded.

Only six *Pinna* specimens were collected for identification of *Pontonia* specimens in the lab. These were identified as *P. pinnophylax* (Fig. 1A). The occupation of *P. rudis* by

shrimps was 20% and occurred only in hosts longer than 15 cm (Fig. 1B). Most shrimps found within the shells were in pairs, and no individual was found among dead *Pinna*.

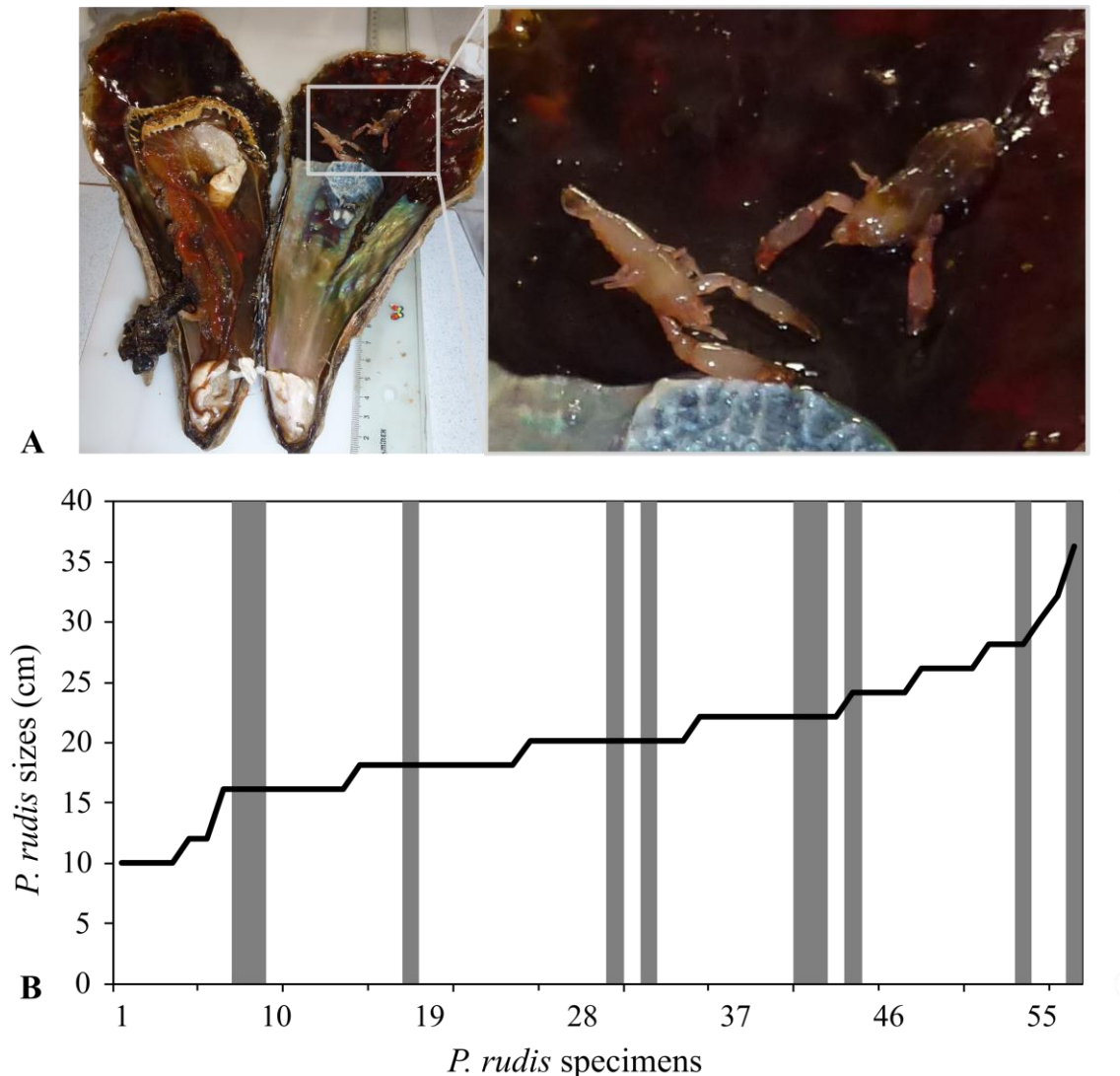


Fig. 1. Association between *Pinna rudis* hosts and *Pontonia pinnophylax* endobionts (photos by E. Lopes). **A)** Two *P. pinnophylax* specimens within a sampled *P. rudis* (more photos available at Morphobank P3976: M740024–M740034). **B)** Shell longitudinal sizes of *P. rudis* in Matiota beach used in the current study. Gray bars represent the *P. rudis* specimens where *P. pinnophylax* were found.

Although recent studies in the Mediterranean have shown that this shrimp is more likely to be found in larger *Pinna nobilis* Linnaeus, 1758 and *P. rudis* (Richardson *et al.* 1997, Rada & Milat 2009), in this study we were able to find it in smaller shells as well. This symbiosis relationship can be extremely important for both species. Shrimps may eat the mollusc pseudofaeces (Yonge, 1953) and

receive sustenance, shelter and assistance in brooding and larval development, while the mollusk may enjoy the protection afforded by cohabitants (Richardson *et al.* 1997, Barreiros *et al.* 2016).

Habitat degradation has been considered the main cause of *P. rudis* population decline, rising its conservation status to the category of vulnerable in some places

(Barea-Azcón *et al.* 2008). In the present study, *P. pinnophylax* was recorded as an endosymbiont of *P. rudis*, confirming its high dependency on rough pen shells for obtaining food and protection (Wirtz & Debelius 2003).

In situ conservation actions of *P. rudis* may thus play an important role in the conservation of *P. pinnophylax* in habitats where refuges are scarce.

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Caixa Postal 163, São Vicente, Cabo Verde
E-mail: zoologiacaboverdiana@gmail.com
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