

New records of the shrimp-like decapods *Alpheus angulosus*, *Alpheus buckupi*, and *Axianassa australis* from Maranhão, Brazil

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ABSTRACT

We provide morphological and genetic evidence to establish the presence/occurrence of *Alpheus angulosus*, *Alpheus buckupi*, and *Axianassa australis* on the coast of Maranhão, Brazil. The specimens were collected in December 2019 by actively searching the estuaries and rocky shores of São Luís Island, northeast of Brazil. In addition to morphological analyses, two mitochondrial genes were obtained (Cytochrome C Oxidase I and 16S), and a phylogenetic analysis was conducted to verify the specimens' identity. Accurate identification is an essential tool to obtain reliable information about the occurrence of the species and thus help assess biodiversity in a highly diverse region. These findings also serve to stimulate future studies in poorly studied areas as well as set a baseline for biodiversity conservation and preservation strategies.

KEYWORDS

Decapoda, molecular markers, Northeast, occurrence data, São Luís Island

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INTRODUCTION

“Upaon-Açu” or São Luís Island is a Brazilian territory that is part of the Golfão Maranhense Archipelago. This region is under the strong influence of the Amazon River plume, and the biodiversity of decapod crustaceans is understudied in this very extensive and diverse coastline (Francini-Filho et al., 2018; Lima and Martinelli-Lemos, 2019; Rodrigues-Inoue et al., 2021).

The genus *Alpheus* Fabricius, 1798 is composed of more than 320 species of snapping shrimps, being the second most species-rich genus within the Caridea (De Grave and Fransen, 2011; WoRMS, 2023a). They inhabit diverse environments and microhabitats such as estuaries, rocky coasts, unconsolidated substrate, and some live in association with other organisms such as sponges and corals (De Grave and Fransen, 2011; Almeida et al., 2018).

The genus *Axianassa* Schmitt, 1924 (Gebiidea) consists of decapods popularly called mud-shrimps, and currently covers about 15 described species (Anker, 2020; WoRMS, 2023b), distributed in the western Atlantic, eastern Pacific, and western Pacific (Anker and Pachelle, 2016; Komai et al., 2020).

We report here new occurrences of the species *Alpheus angulosus* McClure, 2002, *Alpheus buckupi* Almeida, Terossi, Araújo-Silva and Mantelatto, 2013, and *Axianassa australis* Rodrigues and Shimizu, 1992 from São Luiz Island, thus expanding their known northern distribution to the coast of Maranhão, Brazil.

MATERIAL AND METHODS

The specimens were collected during an exploratory field trip carried out in December 2019 using an active search method, along the estuaries and rocky shores of São Luís Island, northeast of Brazil (Fig. 1). After sampling, the specimens were frozen, fixed in 80% ethanol and deposited in Coleção de Crustáceos do Departamento de Biologia (CCDB), Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Universidade de São Paulo, Ribeirão Preto, Brazil: CCDB 6698 (*Al. angulosus*), CCDB 6699, 6700 (*Al. buckupi*), and CCDB 6873 (*Ax. australis*). The identification keys in Soledade and Almeida (2013) and Anker (2010) were used to morphologically identify the *Alpheus* and *Axianassa* species, respectively. In addition, molecular analyses of COI and 16S genes of all collected individuals were performed to increase the accuracy of the identification. The individuals were measured (in mm) with respect to carapace length (CL) under a Leica M250 C stereomicroscope and were categorized as: j = juvenile; ♂ = male; ♀ = non-ovigerous female and ♀_{ov} = ovigerous female.

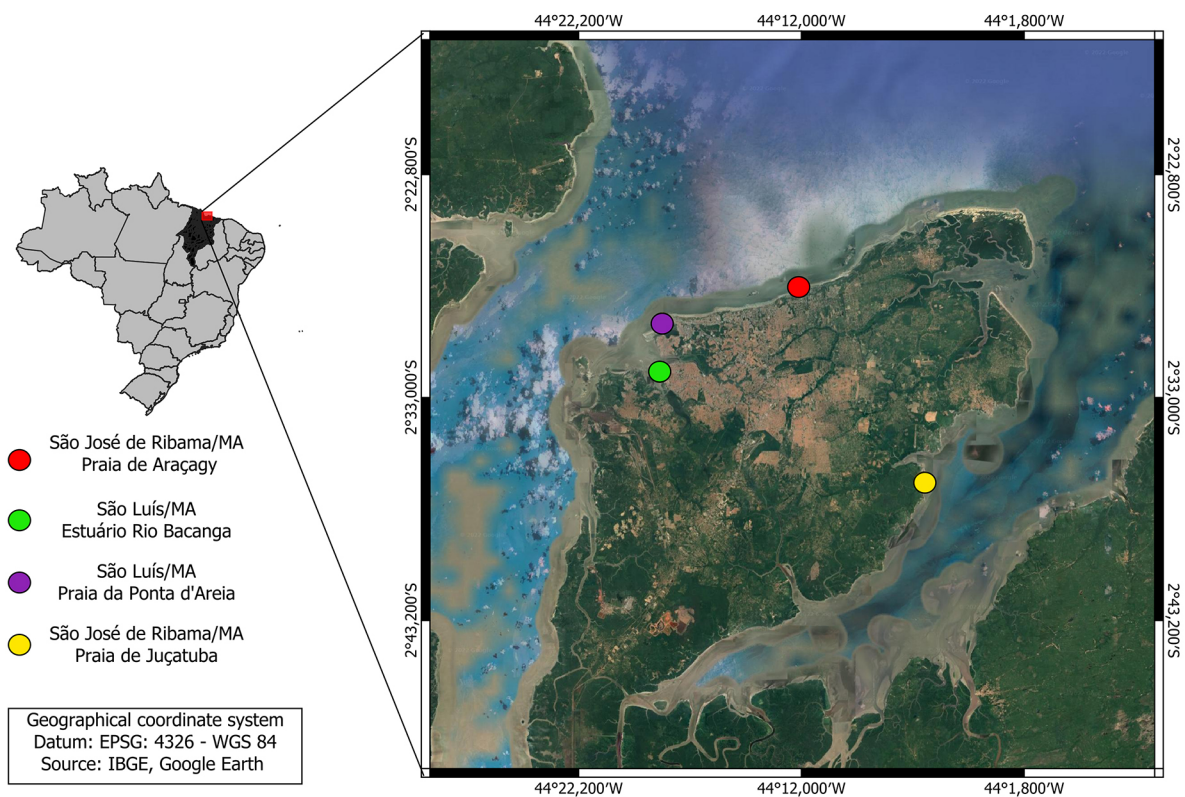


Figure 1. Map of São Luís Island, Maranhão, Brazil, with the new collection points of the specimens (source: IBGE – Instituto Brasileiro de Geografia e Estatística).

Molecular protocols and analysis

Genomic DNA was extracted from the abdominal musculature of each specimen using Chelex® Resin (Estoup et al., 1996) following the manufacturer and Mantelatto et al. (2018) protocols. The COLB2/COH6 primers (Schubart and Huber, 2006; Mantelatto et al., 2016) for *Alpheus* species were used to enlarge the segment of the COI gene and LCOI/HCOI (Folmer et al. 1994) for *Ax. australis* and H2/L2 (Schubart et al., 2000) for 16S for the three species.

The purified PCR products were sent to the Faculdade de Ciências Agrárias e Veterinárias de

Jaboticabal (FCAV), Universidade Estadual Paulista Júlio de Mesquita Filho (UNESP), to be amplified.

The obtained sequences were confirmed by the analysis of both strands and a consensus sequence obtained through the program Geneious 2021.2.2 (Kearse et al., 2012). The regions of the primers and non-readable regions of the sequences were removed and checked for the presence of pseudogenes, and the remaining fragments had their identity verified by comparative alignment in the BLAST system (<http://blast.ncbi.nlm.nih.gov/blast.cgi>). All sequences were published in GenBank (Tab. 1).

Table 1. Details (in bold) of *Alpheus angulosus* McClure, 2002, *Alpheus buckupi* Almeida, Terossi, Araújo-Silva and Mantelatto, 2013, and *Axianassa australis* Rodrigues and Shimizu, 1992 collection, and additional species of Alpheidae Rafinesque, 1815 and Axianassidae Schmitt, 1924 used in the comparison. Voucher refers to specimen and respective catalog numbers from museum collections. Location is the locality of collection of the specimen. Numbers of NCBI GenBank accession of 16S and COI markers are available. Abbreviations: COI = Cytochrome Oxidase subunit I; 16S = 16S rDNA; CCDB = Coleção de Crustáceos do Departamento de Biologia da Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Brazil; MOUFPE = Museu de Oceanografia da Universidade Federal de Pernambuco, Brazil; OUMNH.ZC = Oxford University Museum of Natural History, Oxford, United Kingdom; UESC = Universidade Estadual de Santa Cruz, Ilhéus, Brazil; UF = Florida Museum of Natural History, University of Florida, Gainesville, FL; MZUESC = Museu de Zoologia da Universidade Estadual de Santa Cruz, Ilhéus, Brazil; MV = Museum Victoria, Carlton, Australia.

Species	Voucher	Location	16S	COI	Sequence source
<i>Axianassa australis</i>	CCDB 6873	São José de Ribamar, Maranhão, Brazil	OQ110581	OQ108484	Present study
<i>Axianassa australis</i>	CCDB 7168	Recife, Pernambuco, Brazil	OQ110582	OQ108485	Present study
<i>Alpheus angulosus</i>	CCDB 6698	São José de Ribamar, Maranhão, Brazil	OQ110583	OQ108486	Present study
<i>Alpheus angulosus</i>	CCDB 6698	São José de Ribamar, Maranhão, Brazil	OQ110584	OQ108488	Present study
<i>Alpheus angulosus</i>	CCDB 6698	São José de Ribamar, Maranhão, Brazil	OQ110585	OQ108487	Present study
<i>Alpheus buckupi</i>	CCDB 6699	São Luís, Maranhão, Brazil	OQ110587	OQ108489	Present study
<i>Alpheus buckupi</i>	CCDB 6699	São Luís, Maranhão, Brazil	OQ110588	—	Present study
<i>Alpheus buckupi</i>	CCDB 6700	São Luís, Maranhão, Brazil	OQ110589	OQ108490	Present study
<i>Alpheus estuariensis</i>	CCDB 3787	Porto Seguro, Bahia, Brazil	OQ110586	—	Present study
<i>Salmoneus ortmanni</i>	CCDB 6799	São Sebastião, São Paulo, Brazil	OQ110590	—	Present study
<i>Alpheus carlae</i>	MOUFPE:19795	Ilhéus, Bahia, Brazil	JX286602	—	Almeida et al., 2013
<i>Alpheus carlae</i>	CCDB 4842	Cananéia, São Paulo, Brazil	KU312968	KU312998	Almeida et al., 2018
<i>Alpheus estuariensis</i>	MOUFPE:19794	Itamaracá, Pernambuco, Brazil	JX286607	—	Almeida et al., 2013
<i>Alpheus estuariensis</i>	CCDB 3809	Cananéia, São Paulo, Brazil	JX286608	KU313000	Almeida et al., 2013
<i>Alpheus chacei</i>	MOUFPE:19793	Ilhéus, Bahia, Brazil	JX286606	—	Almeida et al., 2013
<i>Alpheus heterochaelis</i>	UF:23208	Florida, USA	JX286610	—	Almeida et al., 2013
<i>Alpheus formosus</i>	CCDB 2182	São Sebastião, São Paulo, Brazil	KU312969	KU313001	Almeida et al., 2018
<i>Alpheus formosus</i>	UF 32087	Saint Martin	—	MN515447	Hurt et al., 2021
<i>Alpheus intrinsecus</i>	OUMNH.ZC.2011-03-0013	Panama	—	MN515471	Hurt et al., 2021
<i>Alpheus intrinsecus</i>	CCDB 3499	Ubatuba, São Paulo, Brazil	KU312970	KU313002	Almeida et al., 2018
<i>Alpheus intrinsecus</i>	MOUFPE 15610	Rio de Janeiro, Brazil	KU665633	—	Almeida et al., 2018
<i>Alpheus intrinsecus</i>	MOUFPE 15611	Penha, Santa Catarina, Brazil	KU665634	—	Cunha et al., 2017
<i>Alpheus brasileiro</i>	CCDB 4112	Cananéia, São Paulo, Brazil	KU312966	KU312997	Almeida et al., 2018

Table 1. Cont.

Species	Voucher	Location	16S	COI	Sequence source
<i>Alpheus packardii</i>	UF-31909	Saint Martin	—	MN515450	Hurt et al., 2021
<i>Alpheus angulosus</i>	MZUESC 1525	Ilhéus, Bahia, Brazil	—	KU312996	Almeida et al., 2018
<i>Alpheus angulosus</i>	MOUFPE:19792	Ilhéus, Bahia, Brazil	JX286599	—	Almeida et al., 2013
<i>Alpheus buckupi</i>	OUMNH.ZC.2011-06.005	Lagarto Beach, São Tomé and Príncipe	JX286604	—	Almeida et al., 2013
<i>Alpheus buckupi</i>	MOUFPE:19791	Paulista, Pernambuco, Brazil	JX286603	—	Almeida et al., 2013
<i>Alpheus buckupi</i>	UESC 1521	Cairu, Bahia, Brazil	JX286605	—	Almeida et al., 2013
<i>Alpheus buckupi</i>	CCDB 1205	São Sebastião, São Paulo, Brazil	KU312967	—	Almeida et al., 2018
<i>Salmoneus carvachoi</i>	CCDB 4834	Cananéia, São Paulo, Brazil	KU312990	KU313014	Almeida et al., 2018
<i>Synalpheus minus</i>	OUMNH.ZC.2014-04-016	São Paulo, Brazil	—	KJS95115	Hultgren et al., 2014
<i>Synalpheus fritzmuelleri</i>	CCDB 3416	Ubatuba, São Paulo, Brazil	—	KU313015	Almeida et al., 2018
<i>Synalpheus townsendi</i>	CCDB 5630	Ubatuba, São Paulo, Brazil	KU312993	KU313018	Almeida et al., 2018
<i>Axianassa australis</i>	MVJ 44613	São Sebastião, São Paulo, Brazil	EU874948	—	Tudge and Cunningham, 2002; Robles et al., 2009
<i>Axianassa australis</i>	CCDB 1037	São Sebastião, São Paulo, Brazil	MF490232	MF490135	Mantelatto et al., 2018
<i>Upogebia paraffinis</i>	CCDB 3519	Ubatuba, São Paulo, Brazil	MF490235	MF490138	Mantelatto et al., 2018
<i>Upogebia noronhensis</i>	CCDB 3864	Ubatuba, São Paulo, Brazil	MF490234	MF490137	Mantelatto et al., 2018
<i>Upogebia brasiliensis</i>	CCDB 3261	Cananéia, São Paulo, Brazil	MF490233	MF490136	Mantelatto et al., 2018
<i>Audacallichirus mirim</i>	CCDB 2974	Rio Grande do Sul, Brazil	MN237798	—	Robles et al., 2020
<i>Neocallichirus guassutanga</i>	CCDB 5516	São Sebastião, São Paulo, Brazil	MF490165	MF490065	Mantelatto et al., 2018

To confirm the similarity between the sequences generated and those available in GenBank, distance matrix analyses were performed in MEGAX software (Kumar et al., 2018).

The alignment of the consensus sequences was performed in the software MAFFT v.7 (Kato and Toh, 2008; <http://mafft.cbrc.jp/alignment/server/>). Phylogenetic analyses of maximum likelihood were performed for each species and gene using the IQ-TREE program (Miller et al., 2010). The evolutionary model that best adjusted to the data was determined by IQ-TREE according to the Bayesian Information Criterion (BIC) (Luo et al., 2010) and used for tree inference. The branch support was evaluated by ultrafast bootstrap with 1000 replicates. Details about DNA sequences from other species used as a comparative ingroup and the outgroup are in Tab. 1.

RESULTS

Systematics

Infraorder Caridea Dana, 1852

Superfamily Alpheoidea Rafinesque, 1815

Family Alpheidae Rafinesque, 1815

Alpheus angulosus McClure, 2002

(Fig. 2)

Material examined. Brazil — Maranhão: 1 ♂ (CL 8.96 mm), 2 ♀ov (CL 8.67 mm, CL 9.09 mm), CCDB 6698, São José de Ribamar, praia de Araçagi, 02°27'57"S 44°12'08"W, colls. J.N. Teles and N.F. França, 11.xii.2019.

Comparative material. Brazil — Pernambuco: 1 ♂ 1 ♀ov, CCDB 4518, Ipojuca, praia de Serrambi, 08°33'51.28"S 35°01'34.91"W, colls. F.L. Mantelatto and F.B. Mantelatto, 01.i.2013; 1 ♂ 1 ♀ov, CCDB 7316, praia de Carneiros, Tamandaré, 08°41'41.17"S 35°04'28.60"W, coll. G.L. Bochini, 10.xii.2017; 1 ♀, CCDB 7317, rio Massangana, Suape, 08°21'34.49"S 34°57'40.34"W, coll. G.L. Bochini, 27.ix.2019.

Distribution. Western Atlantic — USA (North Carolina to Florida), Gulf of Mexico, Caribbean Sea, French Guyana, Brazil (Maranhão, Atol das Rocas, Fernando de Noronha Islands, Ceará, Paraíba, Bahia, Rio de Janeiro, São Paulo, Santa Catarina, Rio Grande do Sul) (Almeida et al., 2018; present study).



Figure 2. *Alpheus angulosus* McClure, 2002. 1 ♂, CL 8.96 mm, CCDB 6698. Photo: Jeniffer Teles.

Remarks. The record presented herein from São José de Ribamar, Maranhão, extends the northern distribution range of the species in Brazil approximately 345 km from its previous occurrence in Barroquinha, Ceará (Pachelle et al., 2016).

GenBank accession numbers. CCDB 6698: COI (OQ108486-OQ108488); 16S (OQ110583-OQ110585).

***Alpheus buckupi* Almeida, Terossi, Araújo-Silva and Mantelatto, 2013**
(Fig. 3)

Material examined. Brazil — Maranhão: 1 ♂ (CL 7.54 mm), 1 ♀ (CL 8.67 mm, CL 7.58 mm), CCDB 6699, São Luís, estuário rio Bacanga, 02°31'50"S 44°18'29"W, colls. J.N. Teles and N.F. França, 05.xii.2019; 2 ♂ (4.64 mm, 4.85 mm), 1 ♀

(CL 3.66 mm), CCDB 6700, praia da Ponta d'Areia, 02°29'36"S 44°18'22"W, colls. J.N. Teles and N.F. França, 12.xii.2019.

Comparative material. Brazil — Pernambuco: 1 ♂ 1 ♀, paratypes, CCDB 3966), Recife, 08°04'12,15"S 34°52'19,11"W, colls. A.O. Almeida, R.J.C. Paiva and F.S. Santana, 19.viii.2008. — Espírito Santo: 3 ♂, CCDB 4519, Piúma, 20°50'40.5"S 40°43'24.9"W, colls. F.L. Carvalho, D.F. Peiró and R. Robles, 15.vi.2012. — São Paulo: 1 ♂ 1 ♀ov, CCDB 4883, São Sebastião, 23°48'78.1"S 45°24'46.9"W, colls. F.L. Mantelatto and L.M. Pardo, 10.ix.2013.

Distribution. Western Atlantic — Guadeloupe, Venezuela (Orinoco Delta), Brazil (Pará, Maranhão, Ceará, Rio Grande do Norte, Pernambuco, Alagoas, Sergipe, Bahia, São Paulo). Eastern Atlantic — São Tomé and Príncipe (Almeida et al., 2018; present study).



Figure 3. *Alpheus buckupi* Almeida, Terossi, Araújo-Silva and Mantelatto, 2013. 1 ♂, CL 7.54 mm, CCDB 6699. Photo: Jeniffer Teles.

Remarks. Despite the occurrences in the states of Pará and Ceará, this is the first time that the geographical occurrence of *Al. buckupi* is reported in the state of Maranhão.

GenBank accession numbers. CCDB 6699: COI (OQ108489), 16S (OQ110587; OQ110588); CCDB 6700: COI (OQ108490); 16S (OQ110589).

Infraorder Gebiidea de Saint Laurent, 1979

Family Axianassidae Schmitt, 1924

Genus *Axianassa* Schmitt, 1924

***Axianassa australis* Rodrigues and Shimizu, 1992
(Fig. 4)**

Material examined. Brazil — Maranhão: 1 ♂ (CL 9.67 mm), CCDB 6873, São José de Ribamar, praia

de Juçatuba, 02°36'53"S 44°06'23"W, colls. J.N. Teles and N.F. França, 10.xii.2019.

Comparative material. Brazil — Pernambuco: 2 ♂, 1 ♀, 3 ov, CCDB 3097, Sirinhaém, 08°41'28"S 35°06'11"W, colls. F.L. Mantelatto and D. Castiglioni, 07.x.2010; 7 ♂, 3 ♀, CCDB 7168, Recife, 08°04'40"S 34°52'31"W, colls. F.L. Mantelatto, A.S. Rios, G.L. Bochini and F. Balbino, 28.viii.2022. — Espírito Santo: 2 ♂, 2 ov, CCDB 2246, Guarapari, 20°40'01"S 40°29'49"W, colls. F.L. Mantelatto, D.F. Peiró and E.C. Mossolin, 04.xi.2006. — São Paulo: 3 ♂, 2 ♀ 2 j, CCDB 5632, Ubatuba, Araçá, 23°48'78.1"S 45°24'46.9"W, colls. F.L. Mantelatto et al., 02.xii.2014.

Distribution. Western Atlantic — USA (Texas, Florida), southwestern Gulf of Mexico, Caribbean Colombia, Brazil (Maranhão, Ceará, Pernambuco, Sergipe, Bahia, Espírito Santo, São Paulo, Paraná) (Mantelatto et al., 2022; present study).



Figure 4. *Axianassa australis* Rodrigues and Shimizu, 1992. 1 ♂, CL 9.67 mm, CCDB 6873. Photo: Jeniffer Teles.

Remarks. This is the first time that *A. australis* is reported in the state of Maranhão, increasing its geographical distribution by approximately 582 km from the previous northernmost record in Paracuru, Ceará (Pachelle et al., 2016; present study).

GenBank accession numbers. CCDB 6873: COI (OQ108484), 16S (OQ110581); CCDB 7168 — COI (OQ108485), 16S (OQ110582).

Molecular data

The sequences of three individuals of *Al. angulosus* (CCDB 6698) were grouped with specimen from Bahia, Brazil (bootstrap support 91%; 16S gene). The same occurred for *Al. buckupi* (CCDB 6699, 6700) that aligned with individuals from São Tomé and Príncipe; Pernambuco, Brazil; Bahia, Brazil; and São Paulo, Brazil (bootstrap support 98%; 16S) (Fig. 5A).

The COI gene of *Al. angulosus* presented a cluster with the specimen of Ilhéus, Bahia, Brazil (bootstrap support 98%; Fig. 5B). *Alpheus buckupi* did not have sequences for the COI gene available in GenBank, but there was a grouping of the sequences generated in this work (bootstrap support 100%) distant from others *Alpheus* species (Fig. 5B). The divergence average among *Al. angulosus* sequences of the present study and GenBank was 0.53% for COI and 0.20% 16S. *Alpheus buckupi* was 0.80% for COI and 0.43% for 16S.

Both genes (COI and 16S) grouped *Ax. australis* (bootstrap support 99%) with the sequences of individuals from São Paulo, Brazil (Fig. 6A, B). The divergence average among *Ax. australis* sequences of the present study and GenBank was 1.17% for COI and 2.42% for 16S.

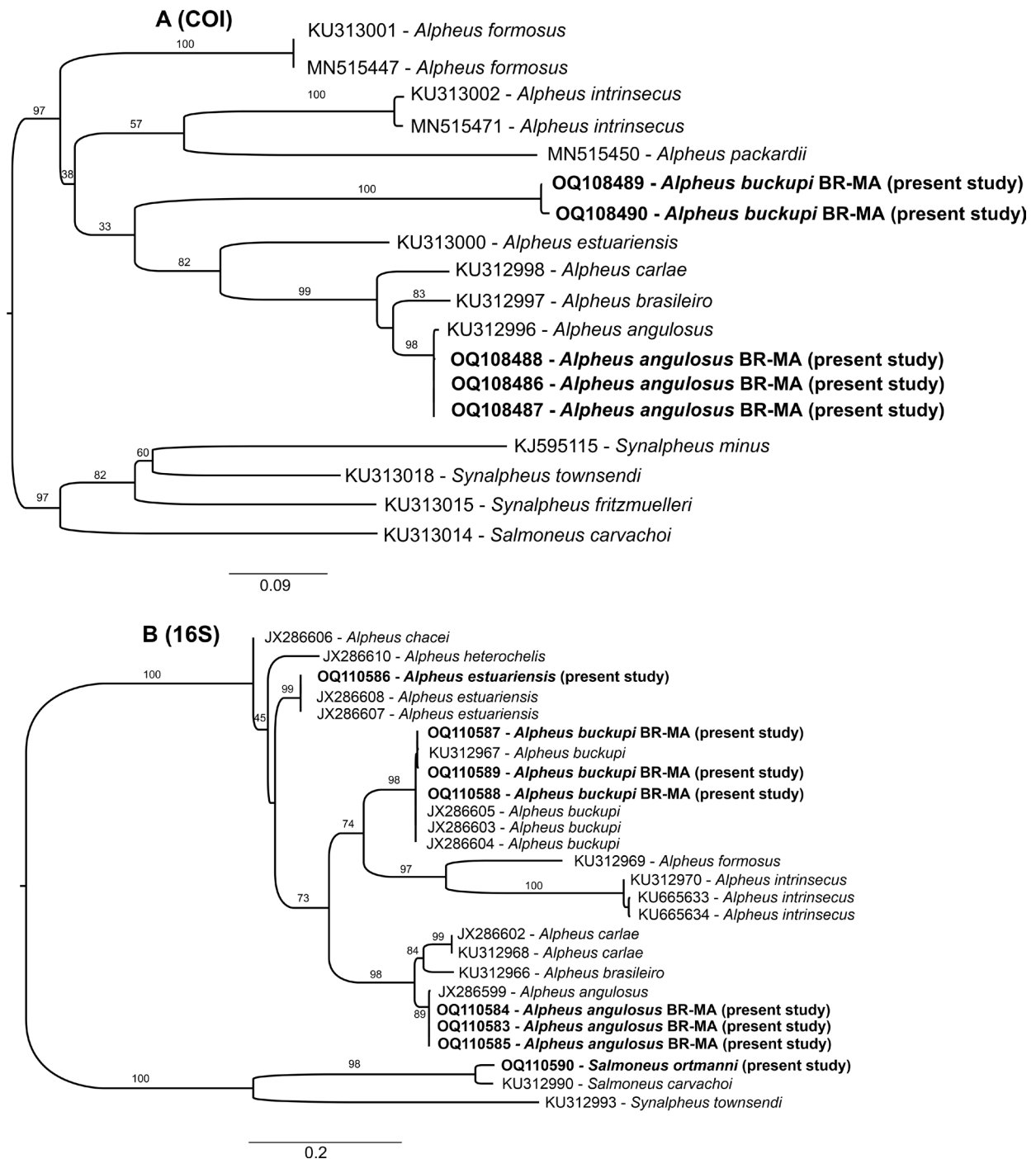


Figure 5. Phylogenetic tree based on Maximum Likelihood analysis of partial fragments of (A) COI and (B) 16S to contextualize the specimens of *Alpheus angulosus* and *Al. buckupi* from Maranhão (Brazil).

DISCUSSION

We obtained robust information (morphological and molecular) to expand the geographical distribution of *Al. angulosus*, *Al. buckupi*, and *Ax. australis* to the coast of Maranhão, Brazil. These data improve the baseline information in biogeographical, conservation, and preservation fields of the Brazilian

fauna. In addition to providing new sequences, the present paper aims to assist studies using databases of occurrence and distribution points of marine species, such as population structure and dynamics, macroecological studies, modeling of past and future species distribution, and local and regional species diversity, among others.

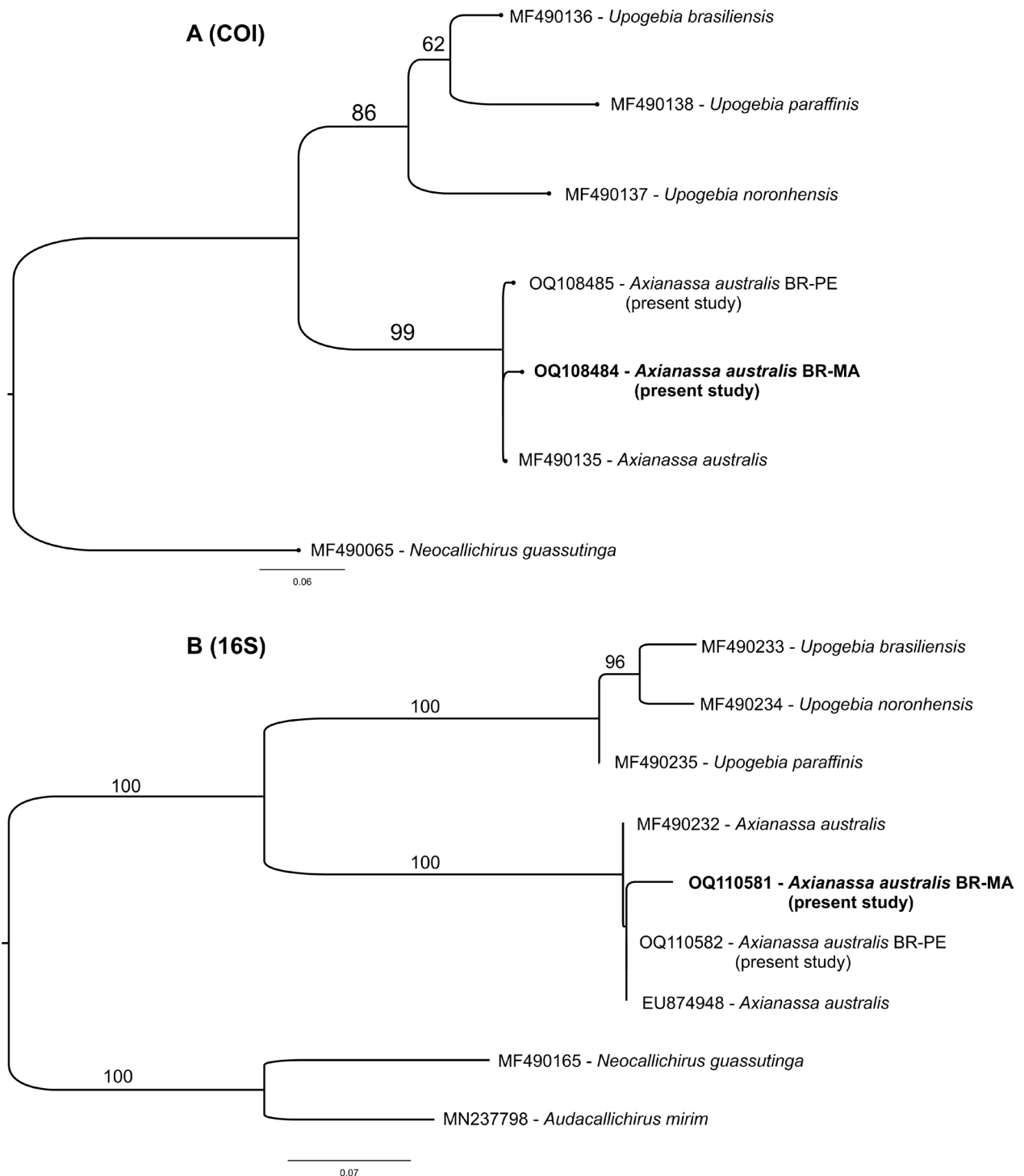


Figure 6. Phylogenetic tree based on Maximum Likelihood analysis of partial fragments of (A) COI and (B) 16S to contextualize the specimens of *Axianassa australis* from Maranhão (Brazil).

In Brazil, the state of Maranhão presents a gap of knowledge in the geographical distribution of marine/estuarine decapod crustaceans, with many examples of species that have records in neighboring states (Piauí and Pará), but with no records in this intervening state. Despite some studies that bring information about brachyuran decapods in Maranhão, the region

presents a great unexplored diversity, mainly due to the great influence of the Amazon River plume, which is part of the Brazilian Amazon Coastal Zone (BACZ) along with the states of Amapá and Pará (Lima and Martinelli-Lemos, 2019). This region is characterized as a transition zone and in some cases, it acts as a geographical barrier between species from

the Caribbean and Brazil delimiting populations (Mandai et al., 2018; Peres and Mantelatto, 2020; Peres et al., 2022). The present records, carried out in a short period, is evidence for the biodiversity potential of this region, and reinforces the importance of exploratory surveys in order to know the biodiversity of poorly known areas. The relevance of the faunal survey (checklists) among the Brazilian regions is unquestionable to protect the biodiversity and serve as support for different researchers. Some examples of great success in this field are the checklist compilations carried out during long periods in some Brazilian states, such as the São Paulo coast line, that reveals a significant diversity of decapods such as Caridea (Almeida et al., 2018; Terossi et al., 2018), Anomura (Mantelatto et al., 2021), Brachyura (Mantelatto et al., 2020), and shrimp-like decapods (Mantelatto et al., 2022); in Ceará (Pachelle et al., 2016), Bahia (Almeida and Coelho, 2008; Almeida et al., 2013), and Santa Catarina (Boos et al., 2012). Also, by larger regions (Coelho Filho, 2006; Coelho et al., 2008; Lima and Martinelli-Lemos, 2019) and oceanic islands, such as Fernando de Noronha (Alves et al., 2008) and Vitória Archipelagos (Alves et al., 2012). Finally, several sporadic records and range extensions or decapods new occurrences along the Brazilian coast have been registered in the last decade (see Almeida et al., 2012; Alves-Junior et al., 2017; 2019; Tamburus et al., 2020). This increase of occurrences is a key condition for taxonomic and biota studies and results from a tremendous effort and actions of different researchers of the Brazilian carcinology community, including collaborative works and stimulus to new groups of researchers to work on regional inventories (Mantelatto et al., 2022).

It is also worth highlighting the importance of molecular markers as powerful tools for the identification of some species (Mantelatto et al., 2018), especially those with cryptic species or species complexes. Genetic sequence analysis allows the identification of species that are fixed in ethanol and lose some morphological characteristics, such as color patterns (essential for morphological identification of snapping shrimps, for example). In addition, it helps non-specialist researchers not make morphological misidentifications of species that have peculiar and difficult to categorize characteristics. We also

emphasize the critical importance of depositing collected specimens in scientific collections and genetic sequences in online platforms for possible future checks and comparisons.

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ADDITIONAL INFORMATION AND DECLARATIONS

Author Contributions

Conceptualization and Design: JNT, FLM. Performed research: JNT, FLM. Acquisition of data: JNT. Analysis and interpretation of data: JNT, FLM. Preparation of figures/tables/maps: JNT. Writing - original draft: JNT. Writing - critical review & editing: FLM. Obtained licence for collection and genetic access, and funding acquisition: FLM.

Consent for publication

All authors declare that they have reviewed the content of the manuscript and gave their consent to submit the document.

Competing interests

The authors declare no competing interest.

Data availability

All study data are included in the article.

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Study association

Nothing to declare.

Study permits

The collections of species conducted in this study complied with current applicable state and federal laws of Brazil (permanent license to FLM for collection of Zoological Material No. 11777-2 MMA/IBAMA/SISBIO and SISGEN registration numbers CCDB = CEA7CD5 and genetic sequences = AE1F319, AE1F319).