



Can citizen science help delimit the geographical distribution of a species? The case of the *Callistoctopus* sp. (“eastern octopus”) on the Brazilian coast

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ABSTRACT

This study presents the first considerations and observations of the occurrence of the octopus *Callistoctopus* sp. on the coast of Brazil. Citizen science, used as a research approach, was fundamental to confirm the presence and delimit the distribution of this species on the Brazilian coast. In all, 187 interviews were conducted with octopus fishers in 17 localities surrounding six marine protected areas, between March 2018 and August 2019. During the development of the work, the number of volunteer participants significantly increased, from the initial 107 specialists to about 2180 local informants, including fishers, divers and diving instructors. By using citizen science, it was possible to extend the area of distribution of this new species from the three existing records of individuals captured for the state of Pernambuco and Bahia to 11 records for more than seven states. The citizen science approach was considered useful for the generation of data that complement scientific research, and its greatest obstacle for use in ethnobiological studies was the need to motivate volunteers to increase the robustness of the collected data.

Keywords: Ladder of Citizen Participation; Octopus Fishers; Participatory Research.

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SIGNIFICANCE STATEMENT

This is the first ethnobiological study of the octopus *Callistoctopus* sp. conducted for the coast of Brazil. This species has not yet been described by science. Citizen science was used as a research approach and proved to be fundamental to confirm the presence and delimit the distribution of this species on the Brazilian coast. Thus, the present work presents the first considerations and observations of one more species of the *Callistoctopus macropus* species complex (Risso, 1826).

INTRODUCTION

Threats to biodiversity have increased steadily in recent decades (Dinerstein et al., 2019; O’Hara et al., 2019; Pilling et al., 2020). For managers to take effective action, these threats must be initially identified and quantified. Any biodiversity conservation efforts, however, require the implementation of high-cost monitoring programs. Unfortunately, government agencies have low budgets and are unable to maintain long-term monitoring programs (Sharpe and Conrad, 2006).

The term citizen science was created in 1837 by William Whewell during his research on ocean tides (Cooper, 2016). Since then, citizen science has played an important role in areas of knowledge such as archaeology, astronomy and natural history, where skills in observation can be as important as the use of equipment (Cohn, 2008). The term is used to give relevance to information obtained through the knowledge of ordinary citizens who work as volunteer researchers and contribute to the collection and/or processing of data as part of scientific research (Dickinson et al. 2012; Donnelly et al. 2014).

Data collection by volunteer researchers has become a convenient alternative for scientists and research agencies that lack information and do not have sufficient financial resources (Pattengill-Semmens; Semmens, 2003; Bonney et al., 2015). Volunteers have participated in projects and studies on climate change (Snyder et al., 2019), biodiversity (Golinelli et al., 2015), invasive species (Andow et al., 2016; Anderson et al., 2017), conservation biology (Goffredo et al., 2004; Crall et al., 2011; Cerrano et al., 2017), ethnoknowledge (Guido and Rodriguez, 2015), ecological restoration (Crall et al., 2012), monitoring of marine biodiversity (Goffredo et al., 2010), population ecology (Branchini et al., 2015) and others. Projects such as the Earthwatch Institute and the National Institute of Invasive Species Science (NIISS) seek the help of these volunteers because they need to collect data in large areas (Silvertown, 2009; Crall et al., 2012). Thus, citizen science is capable of making relevant contributions to marine science, where professional scientific studies and activities are limited by the available human and budgetary resources (Thiel et al., 2014).

In Brazil, projects involving citizen science have only recently begun to gain notoriety (Pinheiro and Chalhub, 2019). For example, the Citizen Science Movement (“Movimento de Ciência Cidadã”, in Portuguese), founded in 2012 in the city of Belém (Pará), originated from the risks and impacts of biotechnologies, particularly transgenic ones. Another example is the Brazilian Biodiversity Information System (“Sistema de Informações sobre a Biodiversidade

Brasileira”, or SiBBr), created in 2014. This project aims to “consolidate a solid national infrastructure of data and content in biodiversity”. For the marine environment, the most prominent proposal, currently, is the Blue Change Citizen Initiative, which seeks to develop citizen research projects in Brazil for the conservation of marine and coastal environments by connecting people with science and vice versa and taking the demands and concerns of society to science (SiBBr, 2020).

The participation of volunteer researchers in underwater monitoring projects reveals some unique challenges. Although the data collected by professional researchers are fundamental and should not be replaced, observations made by recreational divers can provide valuable long-term and large-scale data of the locations where they have dived (Ward-Paige; Lotze, 2011). In addition, citizen science can contribute to territorial management in marine conservation projects (Cerrano et al., 2017).

Based on this perspective of citizen science, the present study used information obtained from the voluntary participation of divers and underwater fishers distributed along the Brazilian coast. This work may be the first to use citizen science as a complementary approach for the identification and distribution of a species of octopus on the Brazilian coast, namely the eastern octopus, *Callistoctopus* sp. (Lima et al., 2020).

MATERIAL AND METHODS

Study area

The study area was delimited using the ad hoc method (Braga et al., 2005), consisting of consultations to “experts” to identify the sites of the possible occurrence of the species *Callistoctopus* sp. and obtain integrated answers based on individual knowledge. Experts, in this case, were considered as being divers with 10 to 30 years of experience in the activity and who were recommended by the consulted dive operators. In this stage, 57 diving schools were contacted via e-mail to delimit the study area. These schools, located between the northeastern and southern regions of Brazil, received a questionnaire containing five specific questions about the possibility of encounters between the divers and the target species of this study during underwater activities (Table 1). For each school, the responsible person was instructed to answer the questions considering, specifically, their region of work. A photograph of the target species was submitted with the questionnaire (Figure 1).

After consultations with diving schools and having the species occurrence limits as Fernando de Noronha Island - PE (Leite and Haimovici, 2006) and Porto



Figure 1. *Callistoctopus* sp. specimen found in a coastal reef of Porto Seguro (BA). First record of its occurrence in Bahia. Photo: Edmilson Conceição (JESUS et al., 2015).

Table 1. Model of the questionnaire sent to diving schools, addressing specific information about the possibility of encounters between the divers and the target species during underwater activities.

1. Have you observed/captured and/or photographed an octopus that had white spots scattered throughout its body? <input type="checkbox"/> Yes <input type="checkbox"/> No
2. If so, mark the depth at which this record occurred: (or sighting) <input type="checkbox"/> < 10m <input type="checkbox"/> > 10m < 50m <input type="checkbox"/> > 50m
3. In which period was this record made? <input type="checkbox"/> Day <input type="checkbox"/> Night
4. How often does this octopus appear? <input type="checkbox"/> All year <input type="checkbox"/> A few months a year; if so, which ones? <input type="checkbox"/> Rarely
5. When was the last time you saw this octopus? <input type="checkbox"/> < 1 year; <input type="checkbox"/> > 1 year < 5 years; <input type="checkbox"/> > 5 years < 10 years <input type="checkbox"/> > 10 years.

Seguro - BA (Jesus et al., 2015), we decided to investigate sites with different uses but that had similar topographic characteristics to the places where scientific evidence existed. Thus, considering the positive responses regarding the occurrence of the species and trying to encompass sites with different uses, seven

marine protected areas (MPA) were defined (Table 2). For this purpose, permission was obtained from the system of authorisation and information on biodiversity (“Sistema de Autorização e Informação em Biodiversidades” - SISBio) under Protocol No. 60468-2.

Table 2. Marine protected areas in which the work was conducted, in the following states of Brazil: Alagoas (AL), Bahia (BA), Pernambuco (PE), Rio de Janeiro (RJ) and Santa Catarina (SC).

Protected Area	Legal Diploma of Creation	State	Area (ha)
Costa dos Corais Environmental Protected Areas	Decree of October 23, 1997	AL/PE	406,085.93
Fernando de Noronha Marine National Park	Decree nº 96,693 of September 14, 1988	PE	10,929.47
Tinharé-Boipeba State Environmental Protected Areas	State Decree nº 1.240 of June 19, 1998	BA	43,300.00
Abrolhos Marine National Park	Decree nº 88,218 of April 6, 1983	BA	87,943.14
Arraial do Cabo Marine Extractive Reserve	Decree of January 3, 1997	RJ	51,601.46
Corumbau Marine Extractive Reserve	Decree of September 21, 2000	BA	89,996.76
Arvoredo Marine Biological Reserve	Decree nº 99,142 of March 12, 1990	SC	17,104.60

Subsequently, we contacted the MPA managers and presidents of the Fisheries Colonies to schedule field activities. Field activities consisted of interviews, diving and direct observation of the fishing activity and collection of specimens. The municipalities of Natal (RN) were also visited, considering that, in Natal, there are reef environments with similar structural characteristics than those of the reefs found in Fernando de Noronha (Castro and Pires, 2001; Mazzei et al., 2017), site of the first record of the species in Brazil (Leite and Haimovici, 2006).

Data collection

Firstly, the president of the Colony of Fishers gave us names of active octopus fishers. These fishers were contacted and after presentation of the team and the project, we started the interviews by showing the fishers photos of 3 species of octopus (*Octopus insularis*, *O. vulgaris* and *Callistoctopus* sp.), on different substrates, sexual gender and sizes so that they could tell us which species knew and occurred in his fishing region. After this first “visual identification”, we directed the interviewee to answer the questions present in the questionnaire. When the fisher did not recognize the species *Callistoctopus* sp. the interview was conducted only on the general aspects of octopus fishing. When the species *Callistoctopus* sp. it was recognized, the interview extended to specific questions about the species. These specific questions were asked according to the information available in the literature about the ecological and behavioral aspects of the species *Callistoctopus macropus* (our initial suspicion). At the end of each interview, we asked the interviewed fisher to indicate two more octopus fishers (snowball method; Bailey, 1994). We ended the interviews, when the indications were repeated more than 3 times. The qualitative-quantitative data (Berto and Nakano, 1999) were collected from March 2018 to Au-

gust 2019 in 17 localities (Add file 1). The anonymity of participants and the confidentiality of the information provided by them were guaranteed under the conditions established in the informed consent statement (TCLE; Authorization No. 2.593.218 of the Research Ethics Committee of the Universidade Estadual de Santa Cruz).

Free diving was carried out in the reef areas and / or close to the rocky shores, since the species occurred in shallow waters. Only in Fernando de Noronha Marine National Park, this modality was not carried out, due to poor weather conditions.

In the phase of direct observation of the fishing activity, all the specimens captured were during the fishing activity (night) in the Morro de São Paulo region (BA). There was no specimen collection at the MPA. The captured specimens were frozen and sent to the Universidade Federal de São Paulo, Instituto do Mar, Fisheries Science Laboratory (LabPESCA) for taxonomic analysis. Tissue samples were taken from each specimen and sent to the Universidade Federal do Pará, Integrated Biological Research Group (GIBI), Center for Advanced Studies in Biodiversity (CEABIO), for genetic analysis. The results of these analyzes will be presented and discussed elsewhere.

Information on the aspects of octopus fishing in the study region was obtained through semi-structured interviews (Add file 2) with octopus fishers, autonomous divers and underwater fishers initially contacted through fishing associations, fishing colonies and diving schools.

For the data obtained through the citizen science, the “ladder of citizen participation” (Arnstein 1969) was used as a theoretical framework, in which each step of the ladder represents a different level of involvement of individuals within the community, ranging from non-participation to citizen empowerment, in the decision-making process (Arnstein, 2013). Thus, this work comprised three “steps” of citizen partici-

pation, considering the involved social actors were notified (via electronic mail), consulted (through questionnaires and interviews) and, after the field activities (initially developed in the pilot project), asked to form a partnership (where the partner fishers suggested the best period for our data collection and sampling and shared the questionnaire and photo in a private group of underwater fishers on social media).

RESULTS

As established in the ad hoc survey method, 57 questionnaires were sent to the diving schools. Of the 57 questionnaires, 32 were returned (rate of return of 56.1%). In 18 of the returned questionnaires, the autonomous divers did not recognise the species, while in the remaining 14 questionnaires, the autonomous divers did recognise the species (Table 3). Two diving schools in Bahia and one in Rio de Janeiro distributed the questionnaire among their divers, totalling around 430 "experts" consulted at this stage. In the diving school of Bahia, 215 divers answered the questionnaire and 16 of these divers (7.44%) recognised the species. No records were obtained for the state of Rio de Janeiro in this stage. According to the responses, the species occurred at night, at depths of less than 10 meters, with rare sightings.

In the field stage (in loco), 187 interviews were conducted with artisanal octopus fishers (members of Fishing Colonies) in 17 localities surrounding the 9 sampled areas (6 MPAs and 3 unprotected areas). The highest number of respondents was at the Corumbau Marine Extractive Reserve (36 fishers, April 2018). The MPA with the lowest number of respondents was the Arvoredo Biological Reserve (15 fishers, November 2018). The average number of respondents per locality was 21. In only one MPA (Arvoredo ReBio), the species was not recognised by the respondents (Add file 1). In March 2020, an underwater fisher made a photographic record of a juvenile specimen in Florianópolis (SC; Add File 3).

Of the 187 fishers interviewed, 132 (70.8%) were able to identify one or two species of octopus (Add file 1). According to them, *Octopus insularis* and *O. vulgaris* were the same species ("common octopus") and *Callistoctopus* sp. was a different species. The respondents used various names to refer to *Callistoctopus* sp., depending on the location (e.g., "eastern octopus", "sand octopus", "cheetah octopus" or "shell octopus"). Other results from the interviews (Add file 2) will be discussed elsewhere.

A total of 16 specimens were captured in Morro de São Paulo (BA) and sent to the Laboratory of Fisheries Sciences (LabPESCA), at the Federal University of São Paulo (SP), for taxonomic, morphometric and genetic analysis (these results will be discussed else-

where). For the municipality of Natal (RN), no sighting or evidence of the occurrence of this octopus was recorded during the field activity (May 2019). Dives were carried out in the reef environments of Maracajaú and interviews were conducted with fishers on the beaches of Pipa, Ponta Negra, Camurupim and Rendingha. During the fieldwork in Maceió (September 2019), no specimen was collected, although one record of its occurrence was obtained in Praia do Francês, through identification by volunteers.

The partnership established with underwater fishers working in Bombinhas (SC) enabled the sharing of specific information about the octopus in a group of fishers on a social media platform, with around 1,750 participants from several Brazilian states. Likely records of the species (provided by informants but needing confirmation) were made on the Brazilian coast for the states of BA (Salvador, Morro de São Paulo and Banco dos Abrolhos), AL (Praia do Francês), PE (Porto de Galinhas) and ES (Aracruz) (Table 4; Figure 2), and photographic records were made for Banco dos Abrolhos, Morro de São Paulo, Porto de Galinhas and Florianópolis (SC). (Add file 3).

The level of citizen participation is shown in Table 5, where it is noted that more than 2,100 participants were informed of the survey; more than 180 were consulted and the partnership was established with 5 partners (with some of these partnerships remaining until the writing date of this work).

DISCUSSION

Citizen science was successfully used in this study. With this approach, it was possible to verify the potential presence and geographical distribution of a newly discovered species of the *Callistoctopus* complex. Our results incorporated data from an extensive geographical area owing to the effective citizen participation of volunteer divers. Thus, the approach used here proved to be relevant for the verification of the presence and potential distribution area of the species.

Science needs inexpensive approaches that effectively help solve environmental issues (Stevenson, 2005). Therefore, alternatives methods, such as ethnoecological studies and science citizen, are used to develop management strategies for aquatic resources in general (Drew, 2005; Goffredo et al., 2010; Khumsri et al., 2008). Moreover, these techniques shorten the time needed to conduct studies and reduce their costs (Lopes et al., 2010; Thiel et al., 2014).

The results of the voluntary collaboration expanded the current knowledge about the possible geographical distribution area of *Callistoctopus* sp. on the Brazilian coast. The resulting expanded knowl-

Table 3. Number of returned questionnaires referring to recognition of the species *Callistoctopus* sp. by autonomous divers from diving schools along the Brazilian coast

State	Acronym	Questionnaires returned			
		Recognized species (N)	%	Unrecognized species (N)	%
Alagoas	AL	2	14.28	2	11.11
Bahia	BA	6	42.86	7	38.88
Pernambuco	PE	2	14.28	2	11.11
Rio de Janeiro	RJ	3	21.43	4	22.22
Santa Catarina	SC	1	7.14	3	16.66

Table 4. Number of responses obtained in the social media group of underwater fishers regarding the presence of octopus *Callistoctopus* sp. along the Brazilian coast. AL: Alagoas; AP: Amapá; BA: Bahia; CE: Ceará; ES: Espírito Santo; MA: Maranhão; PB: Paraíba; PE: Pernambuco; PR: Paraná; RJ: Rio de Janeiro; RN: Rio Grande do Norte; RS: Rio Grande do Sul; SC: Santa Catarina; SP: São Paulo.

Region	State	Responses (N)	Non-recognition (N)	Recognition (N)
North	AP	0	X	X
	AL	16	5	11
	BA	49	7	42
	CE	0	X	X
Northeast	MA	0	X	X
	PB	3	3	0
	PE	13	6	7
	RN	2	2	0
Southeast	ES	5	2	3
	RJ	4	2	2
	SP	0	X	X
	PR	2	2	0
South	SC	7	7	0
	RS	3	3	0
Total	Total	104	39	65

Table 5. Level of involvement and participation of social actors, according to the “ladder of citizen participation”. AL: Alagoas; AP: Amapá; BA: Bahia; CE: Ceará; ES: Espírito Santo; MA: Maranhão; PB: Paraíba; PE: Pernambuco; PR: Paraná; RJ: Rio de Janeiro; RN: Rio Grande do Norte, RS: Rio Grande do Sul; SC: Santa Catarina; SP: São Paulo.

Level of citizen participation	Number of participants	State
Informed	2180	AL; AP; BA; CE; ES; MA; PB; PE; PR; RJ; RN; RS; SC e SP
Consulted	187	AL; BA; PE; RJ e SC
Partners	5	BA; RJ e SC

edge on species distribution agrees with the description in Groom et al. (2019), which states “citizen science broadens opportunities for scientific data collection and provides access to scientific information for community members”. This understanding is one of the best examples of “partnerships”, as they benefit both scientists and volunteer citizens (Jeffrey, 2008). According to Arnstein (1969), the participation of

citizens is essential for the exercise of citizenship. By understanding and classifying the level of involvement and participation of civil society, through the analogy to this theory, it was possible to organise the obtained information and identify potential decision-making agents, in case octopus management strategies should be adopted.

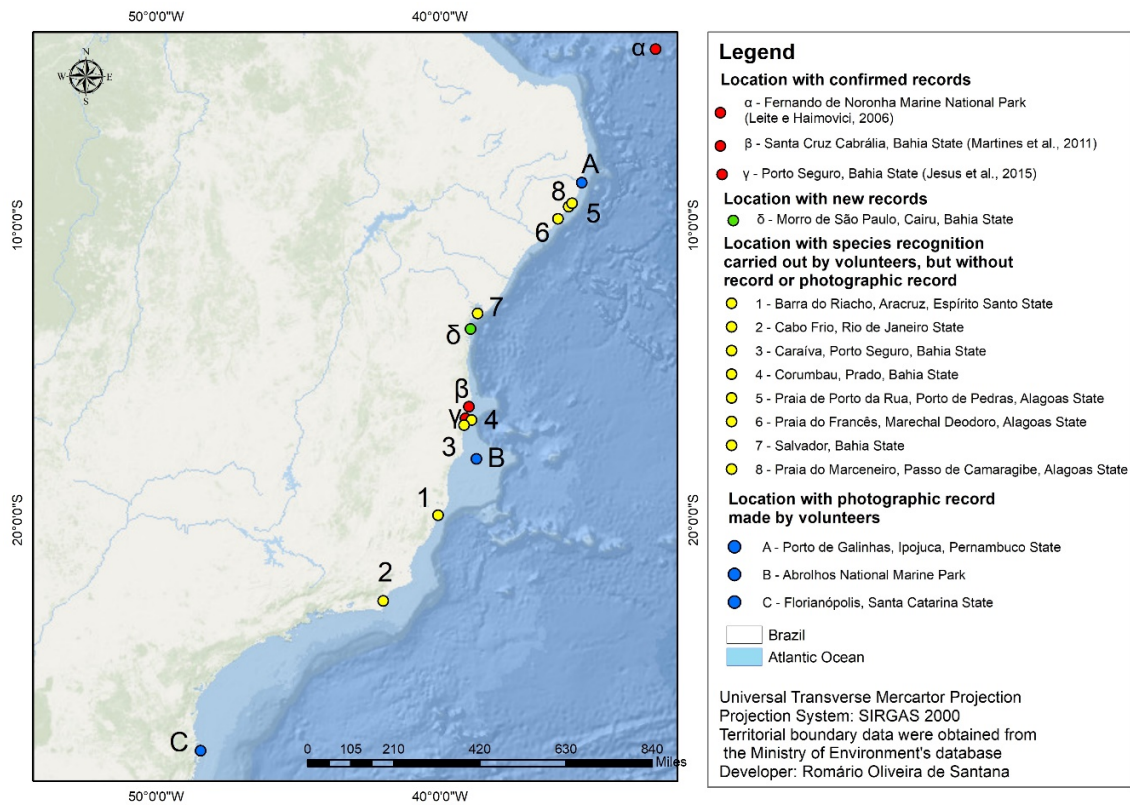


Figure 2. Sites with confirmed presence and potential places of occurrence of the species *Callistoctopus* sp. along the coast of Brazil. α, β, γ and δ: confirmed records; A, B and C: photographic records; 1 to 8: probable occurrence of species.

According to Gibbons (1999), citizen science involves a broad range of factors, from the “simple observation of events and natural characteristics by citizens” to the “important social role of learning about the world around us”, which would amount to “a revolution of science”, in the democratization of learning about the world in which we live. Moreover, citizen science can provide information needed to complement scientific research and enables an expanded analysis of the collected data (Couvet et al., 2008). In this sense, the approach can fundamentally promote coordinated action between social actors, improve the quality of information and facilitate the achievement of common goals (Sauer mann et al., 2020). Following this line of reasoning, citizen science was used as a supplementary approach in field research and as a way of bridging the gap between popular and scientific knowledge. Thus, the results of this study add to the evident and increasing relevance of citizen science for the diagnosis of species distribution maps (Harvey et al., 2018; Chandler et al., 2017).

The use of volunteers in projects has increased in the last two decades, particularly in the areas of

ecology and environmental sciences (Silvertown, 2009; Kosmala et al., 2016). The recognition of citizen science by the scientific community has facilitated its use in monitoring projects, thus increasing understanding of the ecosystem and generating a significant set of spatial and temporal data (Goffredo et al., 2010). However, there is a recurring concern regarding the reliability of data collected using citizen science. To remedy this problem, the collected data must be compared with the available literature, and methods and protocols should be developed to reduce possible errors and detect gaps in the data provided by citizen science (Schmeller et al., 2009; Dickinson; Zuckerberg; Bonter, 2010; Crall et al., 2011; Senabre et al., 2018; Thiel et al., 2014).

Citizen science should not be viewed as a panacea. That is, participatory method cannot be seen as infallible and capable of adequately solving all kinds of problems (Medeiros and Borges, 2007). However, the partnership established with underwater fishers working in Bombinhas (SC) and pot net octopus fishers¹ in Cabo Frio (RJ) proved effective. The fishers from Bombinhas managed to obtain records of the species

¹Net pot: underwater fishing modality, in which octopuses are captured in pots attached to a “line” (longline). In the Resex of Arraial do Cabo, this fishing modality was authorised by Ordinance No. 28, of January 18, 2019.

by using a group on social media with information on its occurrence along the Brazilian coast. In addition, the fishers shared photographic records (Add file 3) and responses indicative of the occurrence of this octopus in these regions, such as (i) period of sighting (night); (ii) depth (less than 10 m); (iii) frequency of sighting (rarely); (iv) size and thickness of the "arms" (long and thin); and (v) presence of the characteristic white spots scattered throughout the body. Therefore, there are strong indications of the occurrence of octopus *Callistoctopus* sp. for the Brazilian states of AL, ES, RJ and SC.

The fact that, in AL, 11 volunteers recognised the species and that three of these volunteers made photographic records provides additional support for future investigations *in loco*, considering approaches that use Local Ecological Knowledge (LEK; Jesus et al., in preparation), such as "informant consensus", can be used to check information (Hanazaki et al., 2010). The states of AL and ES have reef environments with similar structures (Castro and Pires, 2001; Leão et al., 2003; Leão et al., 2016). Thus, the species may also occur in the reefs of ES, as suggested by the volunteers. In the state of RJ, the species was also recognised. The potential recognition of *Callistoctopus* sp. in Cabo Frio (RJ) may be related to the importance of this region as a diving point on the Brazilian coast (Giglio et al., 2019). Consequently, the high number of divers may lead to a search effort with sightings of the species. In addition, Arraial do Cabo is a region where octopus fishing has commercial importance and the species *Octopus vulgaris* is caught throughout the year (Costa et al., 1990). This region is influenced by the Brazil Current (BC), which carries warm and oligotrophic waters southward (Pereira et al., 2009). When the interaction and incomplete mixing between the different water bodies occur, striking oceanographic features are produced, called oceanographic fronts, such as the resurgence fronts (Zanella et al., 1998), found in the Cabo Frio region. These fronts are regions that exhibit great biological abundance due to local productivity (Fournier et al., 1979). According to the interviewed octopus fishers in the region of the Resex of Arraial do Cabo, the species *Callistoctopus* sp. is not often found but is known to occur between January and February. According to Castro (1996), in the Cabo Frio region, the resurgence phenomenon is seasonal and occurs mainly in spring and summer. Thus, the effect of this oceanographic characteristic on the presence of *Callistoctopus* sp. for this region should be investigated.

In SC, a photographic record was made in March 2020 (austral summer) at a distance of about two nautical miles from the coast. According to the fisher, about 20 specimens similar to the one recorded were seated on a seafood bank, located about 5m deep. Lit-

tle is known about behavioral patterns in the octopus early life stages, because of the difficulty in observing young in the wild (Sinn et al., 2001). A field study developed by Ambrose (1988, apud Sinn et al., 2001), indicates the occurrence of a peak of hatching for the species *Octopus bimaculatus*. The author suggests that the slow dispersal capacity of newly hatched individuals may increase competition for food resources and shelter with siblings or conspecifics (or both). It is possible that the specimen registered by the fisher is a newly hatched individual *Callistoctopus* sp. However, more research is needed to support the hypothesis of the presence of the species in the region.

Finally, the collected specimens are still limited to Fernando de Noronha Archipelago (Leite and Haimovici, 2006) and Bahia coast (Jesus et al., 2015 and this work). More in-depth field research involving specimen collection should be carried out between the northern and southern limits suggested in this work to support the photographic records and the evidence described in the present study.

CONCLUSION

The voluntary participation of both autonomous divers and underwater fishers from several Brazilian states brought new information and new records, which extended the study area of the research. In addition, there was a significant increase in the number of participants in this study, from the initial 57 consulted specialists (ad hoc method) to around 2,180 participants. The northern limit of the occurrence of this octopus on the Brazilian coast is extended to the state of Rio Grande do Norte and the southern limit is extended to Florianópolis, state of Santa Catarina. Thus, the present study confirms the relevance of citizen science as a scientific research approach and establishes the occurrence and possible distribution limit of octopus *Callistoctopus* sp. on the Brazilian coast.

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DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors declare that is no conflict of interest.

CONTRIBUTION STATEMENT

Conceived of the presented idea: M.D.J., A.S.
Carried out the data collection: M.D.J.
Carried out the data analysis: M.D.J., C.Z.
Wrote the first draft of the manuscript: M.D.J.
Review and final write of the manuscript: M.D.J., C.Z., A.S.
Supervision: A.S.

REFERENCES

Anderson LG, Chapman JK, Escontrela D, Gough CLA (2017) **The role of conservation volunteers in the detection, monitoring and management of invasive alien lionfish**. *Management of Biological Invasions* 8:589–598 doi: [10.3391/mbi.2017.8.4.14](https://doi.org/10.3391/mbi.2017.8.4.14)

Andow DA, Borgida E, Hurley TM, Williams AL (2016) **Recruitment and Retention of Volunteers in a Citizen Science Network to Detect Invasive Species on Private Lands**. *Environmental Management* 58:606–618. doi: [10.1007/s00267-016-0746-7](https://doi.org/10.1007/s00267-016-0746-7)

Arnstein SR (2002) **Uma Escada Da Participação Cidadã** (1) Sherry R. Arnstei. 1. doi: [10.1017/CBO9781107415324.004](https://doi.org/10.1017/CBO9781107415324.004)

Arnstein SR (1969) **'A Ladder Of Citizen Participation'**. *Journal of the American Planning Association*, 35: 4, 216–224. Available in: DOI: [10.1080/01944366908977225](https://doi.org/10.1080/01944366908977225)

Bailey, KD (1994) **Methods of social research**. The Free Press, New York.

Berto RMVS, Nakano D (2013) **Revisitando a produção científica nos anais do Encontro Nacional de Engenharia de Produção**. *Production* 24:225–232

Berto RMVS, Nakano DN (1999) **A produção científica nos anais do encontro nacional de engenharia de produção: um levantamento de métodos e tipos de pesquisa**. *Production* 9:65–75. DOI: [10.1590/S0103-5131999000200005](https://doi.org/10.1590/S0103-5131999000200005) ISSN:0103-6513 Accessed: 2020-08-31

Bonney R, Shirk JL, Phillips TB, Wiggins A, Ballard HL, Miller-Rushing AJ, Parrish JK (2014) **Next steps for citizen science**. *Science* 343:1436–1437 URL: [10.1126/science.1251554](https://doi.org/10.1126/science.1251554)

Braga B, Hespanhol I, Conejo JGL, Mierzwa JC, de Barros MTL, Spencer M, Eiger S (2005) **Introdução à engenharia ambiental: o desafio do desenvolvimento sustentável**. Pearson Prentice Hall. p. 313. ISBN 85-7605-041-2.

Branchini S, Pensa F, Neri P, Tonucci BM, Mattioli L, Collavo A, Sillingardi ME, Piccinetti C, Zaccanti F, Goffredo S (2015) **Using a citizen science program to monitor coral reef biodiversity through space and time**. *Biodiversity and Conservation*, 24(2), 319–336. doi: [10.1007/s10531-014-0810-7](https://doi.org/10.1007/s10531-014-0810-7)

Castro BD (1996) **Correntes e massas de água da plataforma continental norte de São Paulo**. Livre Docência Thesis. Instituto Oceanográfico da Universidade de São Paulo, São Paulo.

Castro CB, Pires DO (2001) **Brazilian coral reefs: what we already know and what is still missing**. *Bulletin of Marine Science*, 69(2), 357–371.

Cerrano C, Milanese M, Ponti M (2017) **Diving for science-science for diving: volunteer scuba divers support science and conservation in the Mediterranean Sea**. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 27(2), 303–323. DOI: [10.1002/aqc.2663](https://doi.org/10.1002/aqc.2663)

Chandler M, See L, Copas K, Bonde AMZ, López BC, Danielsen F, Legind JK, Masinde S, Miller-Rushing AJ, Newman G, Rosemartin A, Turak E (2017) **Contribution of citizen science towards international biodiversity monitoring**. *Biological Conservation* 213:280–294 URL: [10.1016/j.biocon.2016.09.004](https://doi.org/10.1016/j.biocon.2016.09.004)

Cohn JP (2008) **Citizen Science: Can Volunteers Do Real Research?** *BioScience* 58:192–197 URL: [10.1641/b580303](https://doi.org/10.1641/b580303)

Cooper C (2016) **Citizen science: How ordi-**

nary people are changing the face of discovery.

Abrams. 1 ed. 304 p. ISBN-13: 978-1468308679

Costa PA, Haimovici M (1990) **A pesca de polvos e lulas no litoral do Rio de Janeiro.** *Ciência e Cultura*, 42(12), 1124-1130.

Couvet D, Jiguet F, Julliard R, Levrel H, Teysse-dre A (2008) **Enhancing citizen contributions to biodiversity science and public policy.** *Interdisciplinary science reviews*, 33(1), 95-103. Doi <https://doi.org/10.1179/030801808X26003110.1179/030801808X26003110>

Crall AW, Newman GJ, Stohlgren TJ, Holfelder KA, Graham J, Waller DM (2011) **Assessing citizen science data quality: An invasive species case study.** *Conservation Letters* 4:433–442 URL: [10.1111/j.1755-263X.2011.00196.x](https://doi.org/10.1111/j.1755-263X.2011.00196.x)

Crall AW, Jordan R, Holfelder K, Newman GJ, Graham J, Waller DM (2013) **The impacts of an invasive species citizen science training program on participant attitudes, behavior, and science literacy.** *Public Understanding of Science*, 22(6), 745-764.

Dickinson JL, Zuckerberg B, Bonter DN (2010) **Citizen Science as an Ecological Research Tool: Challenges and Benefits.** *Annual Review of Ecology, Evolution, and Systematics* 41:149–172 URL: [10.1146/annurev-ecolsys-102209-144636](https://doi.org/10.1146/annurev-ecolsys-102209-144636)

Dickinson JL, Shirk J, Bonter D, Bonney R, Crain RL, Martin J, Purcell K (2012) **The current state of citizen science as a tool for ecological research and public engagement.** *Frontiers in Ecology and the Environment*, 10(6), 291-297.

Dinerstein E, Vynne C, Sala E, Joshi AR, Fernando S, Lovejoy TE, Burgess ND (2019) **A global deal for nature: guiding principles, milestones, and targets.** *Science Advances*, 5(4), eaaw2869. URL: [10.1126/sciadv.aaw2869](https://doi.org/10.1126/sciadv.aaw2869)

Donnelly A, Crowe O, Regan E, Begley S, Caffarra A (2014) **The role of citizen science in monitoring biodiversity in Ireland.** *International journal of biometeorology*, 58(6), 1237-1249.

Drew JA (2005) **Use of traditional ecological knowledge in marine conservation.** *Conservation biology*, 19(4), 1286-1293.

Fournier RO, Det MV, Wilson JS, Hargreaves NB (1979) **Influence of the shelf-break front off Nova Scotia on phytoplankton standing stock in winter.** *Journal of the Fisheries Board of Canada*, 36(10), 1228-1237.

Gibbons M (1999) **Science's new social contract with society.** *Nature*, 402(6761), C81-C84. URL: [10.1038/35011576](https://doi.org/10.1038/35011576)

[10.1038/35011576](https://doi.org/10.1038/35011576)

Giglio VJ, Ternes ML, Kassuga AD, Ferreira CE (2019) **Scuba diving and sedentary fish watching: effects of photographer approach on sea-horse behavior.** *Journal of Ecotourism*, 18(2), 142-151.

Goffredo S, Piccinetti C, Zaccanti F (2004) **Volunteers in marine conservation monitoring: A study of the distribution of seahorses carried out in collaboration with recreational scuba divers.** *Conservation Biology* 18:1492–1503 URL: [10.1111/j.1523-1739.2004.00015.x](https://doi.org/10.1111/j.1523-1739.2004.00015.x)

Goffredo S, Pensa F, Neri P, Orlandi A, Gagliardi MS, Velardi A, Zaccanti F (2010) **Unite research with what citizens do for fun: "recreational monitoring" of marine biodiversity.** *Ecological Applications*, 20(8), 2170-2187. URL: [10.1111/j.1523-1739.2004.00015.x](https://doi.org/10.1111/j.1523-1739.2004.00015.x)

Golinelli S, Vega-Villa K, Villa-Romero JF (2015) **Biodiversidad: ciencia ciudadana, saberes originarios y biodiversidad aplicada en la economía social del conocimiento.** *Buen Conocer - FLOK Society Modelos sostenibles y políticas públicas para una economía social del conocimiento común y abierto en el Ecuador* 345–396

Groom Q, Strubbe D, Adriaens T, Davis A, Desmet P, Oldoni D, Vanderhoeven S (2019) **Empowering citizens to inform decision-making as a way forward to support invasive alien species policy.** *Citizen Science: Theory and Practice*, 4(1), 1-11. DOI: [10.5334/cstp.238](https://doi.org/10.5334/cstp.238)

Guido I, Rodríguez C (2015) **Conocimiento popular sobre las aves de Costa Rica.** *Zeledonia* 19 (1): 3-9.

Haimovici M, Andriguetto M, Sunye P (2014) **A pesca marinha e estuarina no Brasil: Estudos de casos multidisciplinares.** 191p. Rio Grande: Editora da FURG. ISBN: 978-85-7566-335-6

Hanazaki N, Mazzeo R, Duarte AR, Souza VC, Rodrigues RR (2010) **Ecologic salience and agreement on the identification of tree species from Brazilian Atlantic Forest.** *Biota Neotropica* 10:77–84 URL: [10.1590/s1676-06032010000100007](https://doi.org/10.1590/s1676-06032010000100007)

Harvey GK, Nelson TA, Paquet PC, Ferster CJ, Fox CH (2018) **Comparing citizen science reports and systematic surveys of marine mammal distributions and densities.** *Biological Conservation*, 226, 92-100. URL: [10.1016/j.biocon.2018.07.024](https://doi.org/10.1016/j.biocon.2018.07.024)

Jesus MD, Gouveia MT de J, Zapelini C, Schiavetti, A (2015) **Pesca artesanal e cadeia produtiva de**

Octopus insularis: o caso dos ambientes recifais do sul da Bahia, Brasil. Gaia Scientia 9:195–204

Kosmala M, Wiggins A, Swanson A, Simmons B (2016) **Assessing data quality in citizen science.** Frontiers in Ecology and the Environment 14:551–560 URL: [10.1002/fee.1436](https://doi.org/10.1002/fee.1436)

Khumsri M, Ruddle K, Shivakoti GP (2009) **Rights and conflicts in the management of fisheries in the Lower Songkhram River Basin, Northeast Thailand.** Environmental Management, 43(4), 557–570.

Leão ZMAN, Kikuchi RKP, Ferreira BP, Neves EG, Sovierzoski HH, Oliveira MDM, Maida M, Correia MD, Johnsson R (2016) **Brazilian coral reefs in a period of global change: A synthesis.** Brazilian Journal of Oceanography 64:97–116 URL: [10.1590/S1679-875920160916064sp2](https://doi.org/10.1590/S1679-875920160916064sp2)

Leão ZMAN, Kikuchi RKP, Testa V (2003) **Corals and coral reefs of Brazil.** In Latin American coral reefs (pp. 9–52). Elsevier Science. URL: [10.1016/B978-044451388-5/50003-5](https://doi.org/10.1016/B978-044451388-5/50003-5)

Leite TS, Haimovici M (2006) **Presente conhecimento da biodiversidade e habitat dos polvos (Cephalopoda: família Octopodidae) de águas rasas das ilhas oceânicas do nordeste brasileiro.** Ilhas Oceânicas Brasileiras – da Pesquisa ao Manejo, 1, 199–214.

Lima FD, Strugnell JM, Leite TS, Lima SM (2020) **A biogeographic framework of octopod species diversification: the role of the Isthmus of Panama.** PeerJ, 8, e8691. URL: [10.7717/peerj.8691](https://doi.org/10.7717/peerj.8691)

Lopes PFM, Silvano R, Begossi A (2010) **Da Biologia a Etnobiologia – Taxonomia e etnotaxonomia, ecologia e etnoecologia.** In: Alves RRN, Mourao JS, Souto WMS (Eds.). A Etnozoologia no Brasil: importância, status atual e perspectivas. 1 ed. NUPPEA, Recife, pp. 67–94.

Mazzei EF, Bertoncini AA, Pinheiro HT, Machado LF, Vilar CC, Guabiroba HC, Hostim-Silva M (2017) **Newly discovered reefs in the southern Abrolhos Bank, Brazil: anthropogenic impacts and urgent conservation needs.** Marine pollution bulletin, 114(1), 123–133. URL: [10.1016/j.marpolbul.2016.08.059](https://doi.org/10.1016/j.marpolbul.2016.08.059)

Medeiros JP, Borges DF (2007) **Participação cidadã no planejamento das ações da Emater-RN.** Revista de Administração Pública 41:63–81 URL: [10.1590/s0034-76122007000100005](https://doi.org/10.1590/s0034-76122007000100005)

O'Hara CC, Villaseñor-Derbez JC, Ralph GM, Halpern BS (2019) **Mapping status and conserva-**

tion of global at-risk marine biodiversity. Conservation Letters 12:1–9 URL: [10.1111/conl.12651](https://doi.org/10.1111/conl.12651)

Pattengill-Semmens CV, Semmens BX (2003) **Conservation and management applications of the reef volunteer fish monitoring program.** In Coastal monitoring through partnerships (pp. 43–50). Springer, Dordrecht.

Pereira MD, Schettini CAF, Omachi CY (2009) **Caracterização de feições oceanográficas na plataforma de Santa Catarina através de imagens orbitais.** Revista Brasileira de Geofísica 27:81–93 URL: [10.1590/s0102-261x2009000100007](https://doi.org/10.1590/s0102-261x2009000100007).

Pilling D, Bélanger J, Hoffmann I (2020) **Declining biodiversity for food and agriculture needs urgent global action.** Nature Food 1:144–147 URL: [10.1038/s43016-020-0040-y](https://doi.org/10.1038/s43016-020-0040-y)

Pinheiro LV, Chalhub T (2019) **Da ciência aberta à ciência cidadã: ampliando perspectivas de inclusão educacional de surdos no Brasil.** Available: Accessed: 09/02/20

Sauermann H, Vohland K, Antoniou V, Balázs B, Göbel C, Karatzas K, Mooney P, Perelló J, Ponti M, Samson R, Winter S (2020) **Citizen science and sustainability transitions.** Research Policy, 49(5), 103978. [10.1016/j.respol.2020.103978](https://doi.org/10.1016/j.respol.2020.103978)

Schmeller DS, Henry PY, Julliard R, Gruber B, Clobert J, Dziock F, Kull T (2009) **Advantages of volunteer-based biodiversity monitoring in Europe.** Conservation biology, 23(2), 307–316. URL: [10.1111/j.1523-1739.2008.01125.x](https://doi.org/10.1111/j.1523-1739.2008.01125.x)

Senabre E, Ferran-Ferrer N, Perelló J (2018) **Diseño participativo de experimentos de ciencia ciudadana.** Comunicar: Revista científica Iberoamericana de comunicación y educación 29–38.

Sharpe A, Conrad C (2006) **Community based ecological monitoring in Nova Scotia: challenges and opportunities.** Environmental monitoring and assessment, 113(1–3), 395–409. URL: [10.1007/s10661-005-9091-7](https://doi.org/10.1007/s10661-005-9091-7)

SiBBR (2020) **Sistema de Informação sobre a Biodiversidade Brasileira:** Disponível em: Last accessed: 18/03/2020

Silvertown J (2009) **A new dawn for citizen science.** Trends in ecology & evolution, 24(9), 467–471.

Sinn DL, Perrin NA, Mather JA, Anderson RC (2001) **Early temperamental traits in an octopus (*Octopus bimaculoides*).** Journal of Comparative Psychology, 115(4), 351. URL: [10.1037/0735-7036.115.4.351](https://doi.org/10.1037/0735-7036.115.4.351)

Snyder JT, Whitney MM, Dam HG, Jacobs MW, Baumann H (2019) **Citizen science observations reveal rapid, multi-decadal ecosystem changes in eastern Long Island Sound.** Marine environmental research, 146, 80-88. URL: [10.1016/j.marenvres.2019.03.007](https://doi.org/10.1016/j.marenvres.2019.03.007)

Stevenson MG (2005) **Traditional knowledge and Sustainable Forest Management.** Sustainable Forest Management Network, p. 18.

Thiel M, Penna-Díaz MA, Luna-Jorquera G, Salas S, Sellanes J, Stotz W (2014) **Citizen scientists and marine research: Volunteer participants, their contributions, and projection for the future.** Oceanography and Marine Biology: An Annual Review 52:257–314

Ward-Paige CA, Lotze HK (2011) **Assessing the**

value of recreational divers for censusing elasmobranchs. PLoS ONE 6: URL: [10.1371/journal.pone.0025609](https://doi.org/10.1371/journal.pone.0025609)

Zanella JFI, Gonçalves GA e Möller Jr OO (1998) **Análise da variação espaço-temporal das frentes térmicas de quebra de plataforma e feições associadas no Oceano Atlântico Sul-Occidental entre 25°S e 37°S.** In: Anais IX Simpósio Brasileiro de Sensoriamento Remoto, Santos, Brasil, INPE, 861-87.

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Additional Files

Add File 1. Locations visited during field activities from March 2018 to August 2019. In all, 17 localities were visited in 7 states, and 187 interviews were conducted. *<http://www.mma.gov.br/areas-protegidas/unidades-de-conservacao>. UF: Federal Unit; MPA: Marine protected area; SNUC: National System of Conservation Units; IUCN: International Union for Conservation of Nature; APA: Environmental Protection Area; PARNA: National Park; Resex: Extractive Reserve; Rebio: Biological Reserve.

Site	State	MPA	MPA class (SNUC/IUCN)	Presence of the species	Popular name	Number of interviewees
Porto de Pedras						
Porto da Rua	AL	Costa dos Corais EPA	Sustainable Use / V	Yes	Does not have	16
Praia do Marceneiro						
Passo de Camaragibe						
Caravelas	BA	Abrolhos MNP	Full Protection II	Yes	Does not have	35
Morro de São Paulo	BA	Tinharé-Boipeba EPA	Sustainable Use / V	Yes	Polvo de areia	30
Ilha de Boipeba						
Caraíva						
Corumbau	BA	Corumbau MER	Sustainable Use / VI	Yes	Polvo de leste	36
Cumuruxatiba						
Jericoacoara	CE	Não se aplica	not applicable	No	Does not have	
Barrinha						
Ilha de Fernando de Noronha	PE	Fernando de Noronha MNP	Full Protection / II	Yes	Does not have	15
Arraial do Cabo	RJ	Arraial do Cabo MER	Sustainable Use / VI	Yes	Polvo chita	20
Cabo Frio						
Natal	RN	Não se aplica	not applicable	No	Does not have	10
Bombinhas	SC	Arvoredo MBR	Full Protection / I	No	Does not have	15
Total						187

Add File 2. Field Research Form - Local Ecological Knowledge (LEK).

Location: _ Municipality: _

- 1 - Name of fisher:
2 - Nickname of fisher:
3 - Gender: () Male () Female
4 - Age:

General aspects of octopus fishing

4. Who taught you how to fish octopus?
() Parents () Grandparents () Friends () Alone;
5. Do you use traps to fish octopus?
() Yes; Which? () No
6. Do you use any tools to fish octopus?
() Yes; Which? () No
7. Do you dive to fish octopus?
() Yes; () No; () Sometimes;
8. How do you classify octopus fishing in this region?
() artisanal; () industrial; () do not know

Seasonality of octopus fishing

9. How often do you fish octopus?
() Daily; () Weekly; () Fortnightly; () Monthly;
10. In which period do you fish octopus?
() Day; () Night;
11. Is octopus fishing influenced by the tide?
() Yes; () No;
12. In which tide do you fish octopus?
() Low; () High;
13. Does the lunar phase influence octopus fishing?
() Yes; () No;
14. In which lunar phase(s) do you fish octopus?
() Full; () Waning; () Waxing; () New

Catch effort

15. Do fish octopus alone?
() Yes; () No;
16. How long does an octopus fishery last?
() ;3h; () ;3h
17. How many kilograms of octopus do you fish per fishery?
() ;10kg; () ;10Kg
18. How much did the smallest octopus you fished weigh?
() ;500g; () ; 500g;
19. How much did the largest octopus you fished weigh?
() ;2kg; () ;2Kg

Sales

20. Are you a member of a fishing colony?
() Yes; Which? () No
21. Is octopus fishing your main work activity?
() Yes () No
22. Do you sell all the octopuses you fish?
() Yes; To whom? () No;
23. Do you consume all the octopuses you fish?
() Yes; () No;

24. Do you know how to differentiate male octopus from female octopus?

Yes; No;

25. Do you think there is more than one type of octopus in your region?

Yes; No;

Aspects of octopus fishing for *Callistoctopus*

26. Have you seen/captured and/or photographed an octopus that had white spots all over its body?

Yes No

27. If your answer was "yes", do you remember the size of this octopus?

cm kg

28. What was the size of the largest octopus of this "kind" you fished?

29. What year was it fished?

30. Where did you fish this octopus?

31. Which fishing gear did you use?

32. How many octopuses of this species did you catch on your best fishing day?

33. In what month and at what time did this happen?

34. What year?

35. Where did you fish?

36. What factor do you most take into account to differentiate this octopus from the common octopus?

Size Weight Colour

37. Regarding the colour, how do you differentiate this octopus from the ordinary octopus?

38. How deep is the place where this octopus is found?

<1m;5m; <5m;10m; <10m.

Add File 3. Records of the octopus *Callistoctopus* sp. in (A, left) Banco dos Abrolhos (BA), unknow author; (B, above) Porto de Galinhas (PE), Léo Blanke Samson; (C, below) Morro de São Paulo (BA), M.D.J.; and (D, right) Florianópolis (SC), Tiago Taquini.

