

1 **Crab fisherman communities in north Brazil: a new high risk population for**
2 **vampire bat rabies**

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18

Abstract

19 An outbreak of human rabies transmitted by hematophagous bats occurred in 2018 in the
20 state of Pará, Brazil, eastern Amazon, after 14 years with no record of the disease. It is
21 necessary to understand the epidemiological characteristics of these attacks to protect the
22 local population. This study aimed to characterize attacks of humans by vampire bats in
23 the municipality of São João da Ponta, Pará state, Brazil, from 2013 to 2015. All
24 individuals attacked by bats who sought medical care during the study period (n=5) were
25 identified in the Notifiable Diseases Information System (SINAN) database and answered
26 a questionnaire about the circumstances of the attack. Using snowball sampling, seed
27 cases identified other individuals who were attacked in the same period but did not seek
28 medical care (n=61), totalizing 66 people attacked in the same period. The interviewees

29 were male (92.4%), adults between 20 and 50 years old (69.6%) and had completed
30 elementary education (86.3%). Most were rural residents (92.4%) and crab fishermen
31 (79.3%). The interviewees (92.4%) identified the mangrove of the Mãe Grande de Curuçá
32 extractive reserve as an area conducive to attacks by vampire bats, where groups of
33 fishermen sometimes concentrate for days for crab fishing, often living in improvised
34 dwellings without walls and covered by tarps or straw (88.8%). The wounds were single
35 bites (71.2%) and were located on the lower limbs (93.9%). Overall, 42.4% of participants
36 had been bitten more than four times throughout their life (range 1-23 attacks).
37 Participants were unaware of the risk of contracting rabies by the bite (95.4%). Using São
38 João da Ponta as a model, this study shows that bat attacks are an essentially occupational
39 problem in the study region. Indeed, for each reported attack, there are 12.2 unreported
40 cases. It is necessary to develop strategies to reach this population for prophylactic
41 treatment.

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43 **Author Summary**

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45 Different from which occurs worldwide in relation to rabies transmission, in Amazon
46 region, vampire bat is involved on direct transmission of rabies virus to humans when
47 searching for bloodmeal. It is common in the state of Pará, Eastern Amazon, large areas
48 inhabited near forests and mangroves. People living there use forest natural resources as
49 a way of income and sustenance and these working conditions is what our study points
50 out as an important factor for aggressions predisposition. Here this subject is shown as an
51 occupational problem. This study also quantified for the first time underreported human's
52 aggressions by bats in Amazon, using the snowball sampling, which valued the
53 relationship between individuals to reach the target population. Based on these results,

54 rabies surveillance may direct actions for prevention and health education for these
55 individuals, including changes in notifications forms and suggesting pre-exposure
56 prophylaxis in vaccination calendar of the Brazilian Ministry of Health for these
57 individuals exposed to the rabies virus.

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76 **Introduction**

77 In general, the causal factors of rabies are manifold. The epidemiological cycle of
78 the viral agent is complex and involves several mammalian hosts. Many researchers
79 consider contact with the wild reservoir, human population mobility, and the social and
80 cultural characteristics of a population as the main determinants for onset of the disease.
81 The high impact of rabies transmission by vampire bats in the Amazon region is
82 unquestionable [1-3].

83 Climate, seasonality, proximity to the forest, and the presence of livestock and
84 natural prey provide conditions conducive to the proliferation of vampire bats in the
85 Amazon. However, this in itself does not determine the occurrence of bites and
86 transmission of rabies in humans. It is the relationships between humans and the
87 environment that place human populations at epidemiological risk, which is also
88 associated with the lack of medical care, poverty and low level education [4,5].

89 This relationship between humans and the environment is reflected in the use of
90 the mangroves' natural resources by the families in that region. The municipality of São
91 João da Ponta, Pará state (PA), is located in an Extractive Reserve (São João da Ponta
92 RESEX) in the Eastern Amazon and is surrounded by other conservation units. The main
93 economic activity of the municipality is swamp ghost crab (*Ucides cordatus*) fishing [6].
94 Informal conversations with the population indicated that many residents in the
95 municipality had been attacked by bats but did not seek medical care.

96 According to the guidelines of the Health Surveillance Department of the Ministry
97 of Health (SVS/MS), bat bites are subject to mandatory notification throughout Brazil.
98 Every case of a bite or attack involving bats must be notified to health authorities using
99 the Notifiable Diseases Information System (SINAN) and completing the human anti-
100 rabies treatment notification form [7]. This form collects identification data of the

101 notifying unit and agent, patient identification, characteristics of the injury, characteristics
102 of the animal responsible for the attack (in cases involving dogs or cats), place of
103 residence and treatment regimen. This form must be completed at each visit and sent to
104 the appropriate department for processing. Although this form has a lot of information to
105 aid in rabies surveillance, it does not provide a record of the circumstances of the attack,
106 which is a key for the surveillance of cases in which the attacking animal is a vampire
107 bat.

108 To help in the recognition of areas where populations are susceptible to vampire
109 bat attacks, and assuming that the population of the municipality of São João da Ponta is
110 representative of the crab fishermen riverside communities in Amazon RESEX area study
111 attacks by vampire bats in mangrove areas of the Eastern Amazon, Pará, Brazil.

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113 **Methods**

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115 **Ethical considerations**

116 This study was conducted with the authorization of the National Research Ethics
117 Commission (Portuguese acronym: CONEP) of the National Health Council (Portuguese
118 acronym: CNS; registration number CAAE: 49593315.1.0000.0018), the Brazilian
119 Institute of the Environment and the Chico Mendes Institute for Biodiversity
120 Conservation (Portuguese acronym: ICMBio; registration number 50344-1). All study
121 participants provided written informed consent.

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123 **Description of the study area**

124 The Salgado micro-region in Pará comprises 11 municipalities that are home to five
125 Marine Extractive Reserves (RESEX): São João da Ponta RESEX, where the

126 municipality under study is located, Maracanã RESEX, Mocapajuba RESEX in São
127 Caetano de Odivelas, Mestre Lucindo RESEX in Marapanim, and Mãe Grande de Curuçá
128 RESEX. The latter covers practically the entire territory of the municipality of Curuçá-
129 PA. The climate is hot and humid, with a rainy season (from January to June) and a dry
130 season (from July to December) [8][9]. The vegetation is composed of moderately
131 preserved mangrove forest with species such as *Rhizophora mangle*, *Avicennia*
132 *germinans* and *Laguncularia racemosa* [10](Figure 1).

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134 **Data collection and analysis**

135 Information of individuals attacked by bats in São João da Ponta municipality
136 between 2013 and 2015 were from Notifiable Diseases Information System (SINAN).
137 This period was selected to prevent the interviewee from having difficulty remembering
138 the episode and answering the questions.

139 These individuals were visited in their homes, and during these visits, the study
140 objectives were explained, and the informed consent form was signed. Subsequently, a
141 semi-structured questionnaire was used to collect data on the circumstances of the attack,
142 such as location and time of the attack, type of attack, time elapsed between attack and
143 anti-rabies treatment, frequency of attack, professional occupation of the attacked
144 individuals and structure of the household or shelter where the attack occurred.

145 A non-probabilistic snowball sampling technique was used to obtain information
146 on individuals who were attacked by bats during the same period but did not seek medical
147 care. The seeds were the cases reported in SINAN during the study period [11].
148 Individuals reached by this method were also interviewed and all locations indicated by
149 the interviewees as the area of the attack were georeferenced.

150 The descriptive statistical analysis of the data was performed using SPSS v. 20. A
151 geographic database was created with the coordinates of the locations of the attacks.
152 Using the cartographic databases of the Brazilian Institute of Geography and Statistics
153 (IBGE), the spatial distribution of cases was analyzed in ArcGIS™ 10.1. The
154 relationships between the individuals reached by snowball sampling was visualized using
155 R.

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157 **Results**

158 Between 2013 and 2015, five residents of the São João da Ponta municipality
159 sought anti-rabies treatment after being attacked by vampire bats and therefore were
160 registered in SINAN. These individuals identified another 141 individuals who were
161 attacked by bats in the same period. Of those, 61 were interviewed and the others 80
162 individuals were disregarded in the analysis because they no longer lived in the
163 community or were bitten for more than three years or refused to answer the questions
164 and we could not confirm the aggression. Therefore, for each individual who sought care,
165 there were at list 12.2 cases that were not reported. The communication network between
166 these individuals is illustrated in Figure 2. We can observe that there are individuals who
167 have more indications. They are individuals better known in the community. In contrast,
168 there are few individuals who know more individuals who have been attacked by bats. To
169 these, besides being more connected with the others in the network, they have high
170 "PageRank" (centrality measures that reflects how much is indicated by the others of the
171 network and those that indicate also have greater popularity). So, we can admit that people
172 have neighbors that have more indications than them, corroborated by the article of Feld
173 (1991) [12]. One of these more connected individuals was a Community Health Agent, a
174 professional that visit households daily as a municipality action of preventive medicine.

175 Among the victims, 10 (15.1%) reported that the attacks occurred in their homes
 176 or in areas near the São João da Ponta Extractive Reserve, whereas the majority (84.9%)
 177 were attacked in the mangrove areas of the Mãe Grande de Curuçá Extractive Reserve in
 178 Curuçá municipality, a neighboring city (Figure 3).

179 Nineteen sites were identified as locations of attacks: 14 in the Curuçá RESEX,
 180 four in the São João da Ponta RESEX and one in the Marapanim RESEX. The Cuimiri
 181 and Pacamorema beaches which are both located in Curuçá, accounted for the highest
 182 proportions of bites, 22.7% and 10.6% respectively. Figure 4 shows the route traveled by
 183 the crab fishermen between the locations of the attack and their city of origin, where they
 184 would seek anti-rabies treatment.

185 The attacked individuals were mostly male (92.4%) and adult (69.6%) and had
 186 less than 4 years formal school education (54.4%). Most lived in the rural area of the city
 187 (92.4%) and were crab fishermen (79.3%) (Table 1).

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189 Table 1- Characteristics of individuals bitten by bats in the São João da Ponta
 190 municipality, Pará, Brazil.

VARIABLES	RESPONSE IN DESCENDING ORDER OF FREQUENCY (%)		
	1 ^a	2 ^a	3 ^a
CHARACTERISTICS OF GRAZING			
Ocupation	Crabfishing (79.3)	Student (12.1)	Farmer (6.1)
Sexo	Male (92.4)	Female (7.6)	-
Age	20 to 50 (69.9)	10 to 20 (28.8)	less than 10 (1.5)
CHARACTERISTICS OF THE PLACE OF AGGRESSION			
Type of home	Tent or straw taps (88.8)	Other (without wall) (10.5)	Masonry (with wall and ceiling) (7.5)
Are there animals at the scene of the aggression?	Wild (75.8)	Domestic (48.5)	-

How many people were at the scene of the aggression?	More than five (63.3)	Two to five (24.1)	One (4.5)
Was there any light source in place?	Yes (87.9)	No (12.1)	-
There is fresh water on site?	Yes (59.1)	No (40.9)	-
Where were you bitten??	Beach (56.1)	Mangrove (30.3)	“Tiso” (3.0)
In what circumstances have you been bitten?	Fishing (83.1)	At leisure (6.2)	Others (6.2)
At what time of year?	Seca (54.5)	Chuvosa (45.5)	-
FEATURES OF THE INJURY			
How many times have you been bitten in the last 3 years?	One (33.3)	More than five (25.8)	Two (21.2)
When was the last aggression?	1 to 3 anos (37.9)	2 to 6 months (34.8)	7 months to 1 any (16.7)
What was the amount of bites in the last attack?	More than tree (45.5)	One (33.3)	Two (21.2)
Type of Injury	Single (71.2)	Multiple (28.8)	-
Anatomical location of the wound	Lower member (80.8)	Head (12.8)	Upper limb (5.13)
Did you look for the health unit?	No (86.4)	Yes (13.6)	-
Do you believe that the bat bite causes any disease?	Yes (80.3)	No (19.7)	-
Do you know what rabies is?	No (94.5)	yes (5.5)	-

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192 The interviewees reported that during crab fishing, they gather for days in
193 makeshift dwellings without walls and covered by tarp or straw (88.8%) (Figure 4). In
194 most cases, these shacks were set up in drier areas within the mangrove (30.3%) or on
195 beaches (56.1%), less than five kilometers from the forest (73.3%) and freshwater bodies
196 (45.4%). In addition, many fishermen reported that bats sheltered in a tree typical of the
197 mangrove area, commonly known as black mangrove (*Avicennia germinans*) (80.3%).
198 Most of the interviewees reported the presence of domestic animals like dogs (56.5%),
199 domestic birds (23.9%) and bovine (10.9%) where attacks occurred. Wild animals were

200 also observed (75.8%), with raccoon (*Procyon cancrivorus*) (26.1%), scarlet ibis
201 (*Eudocimus ruber*), great egret (*Ardea alba*) (23.5%) and monkey (19.1%) being the most
202 commonly reported species. Some interviewees had found lesions suggestive of bat
203 attacks on dogs (42.9%) and domestic birds (10.6%).

204 On the nights that the attacks occurred, most of the individuals (63.6%) were in a
205 group with more than five fishermen in the same shack (ranging from 2 to 12 people),
206 and 33.3% reported that others were also attacked the same night. The shelters typically
207 had a light source (87.9%) such as a lantern, a bonfire or an oil lamp that was usually
208 extinguished by strong beach winds throughout the night.

209 When questioned about the frequency of attacks, most reported having been
210 attacked more than four times. The number of attacks by bats during the life ranged from
211 1 to 18. In most cases (34.8%), the most recent episodes had occurred between 2 and 6
212 months prior to the interview, more frequently in the drier season (54.4%). In general, the
213 injuries were single bites (71.2%) and were located on the lower limbs (80.8%). Among
214 those who sought care (i.e., the seeds, 13.6%), all completed the prophylactic regimen
215 with 5 doses of vaccine and serum.

216 Questions addressing respondents' perceptions regarding the risks associated with
217 bat bites and their consequences revealed that most individuals did not use any type of
218 personal protection equipment against bat attacks (63.6%). Those who claimed to use
219 some type of protection used mosquito netting, "sapato de mangué" (resistant fabric
220 wrapped around their feet), bonfires, or fishing nets around the shack as a physical barrier.
221 Most (80.3%) were unaware of the risk of rabies transmission through a bat bite or even
222 unaware of rabies (94.5%). Of those attacked who did not seek medical care, 66.7%
223 reported "not caring about what happened", 13.6% did not know how to respond, and
224 7.6% mentioned the distance from the healthcare unit.

225

226 **Discussion**

227 This is the first study to quantify the underreporting of bat attacks in humans in
228 the Amazon using the snowball sampling method, which capitalized on relationships
229 between individuals to reach the target population. Network analysis was useful in
230 identifying the people most commonly mentioned by the community in relation to bat
231 attacks, and it can be applied to identify key individuals who can be the focus of more
232 intense health surveillance activities. People identified by the network can be great allies
233 in implementing interventions to change habits and attitudes that may hinder prevention.
234 Indeed, it can be useful to optimize Communities Health Agents job, when bitten people
235 active search is necessary.

236 Human behavior, in particular the lack of knowledge in this study population
237 regarding the predictable consequences of vampire bat bites hinders the use of SINAN
238 quantitative reports as a reliable data source to establish public health policies for rabies
239 transmission in these areas. This is because the number of people attacked by bats in this
240 region is much higher than that recorded in the system. Moreover, the reports do not
241 include the locations of attacks or the bat species involved. Although this characterization
242 was carried in municipality of Pará state, São João da Ponta, we believe that it is reflective
243 of the situation in other municipalities of the Salgado microrregion, which have similar
244 geographic and cultural characteristics.

245 Strategies for rabies prevention in vulnerable populations in Amazon regions have
246 been previously reviewed in the literature [1,3,4]. In fact, it has already been proposed
247 that the SINAN form be changed to include fields related to dog and cat behavior to
248 support animal rabies surveillance and prophylactic measures [13]. Although these
249 changes have not yet been incorporated, this study demonstrates the need to adapt the

250 form to include bat attacks, given that animal attacks relevant to rabies transmission in
251 the Salgado microregion and the whole Amazon typically involve different species than
252 in other regions [14]. The fact that these people are generally not bitten in their homes
253 but, rather, in other circumstances demonstrates that the inclusion in the SINAN form of
254 a field to report the location of attacks is necessary to better prevent vampire bat bites.

255 This study also shows for the first time that living conditions in the mangrove are
256 important factors in bat attacks in the Amazon. Respondents reported that in these areas,
257 attacks by bats have been occurring for a long time and have never resulted in death. In
258 fact, there are no reports of human deaths from the rabies virus in the study region, and
259 there were no reported cases of neurological syndromes in livestock between 2004 and
260 2013 [23]. However, there are no studies on the circulation of rabies virus in this micro-
261 region and the possibility of inexistent or inadequate communication between healthcare
262 and agricultural services cannot be ruled out [16]. Therefore, based on the evidence of
263 human attacks reported here and the underreporting of bites, the study region cannot be
264 considered as an area of controlled rabies transmission. When in doubt about whether the
265 virus is circulating, it would be prudent to define a policy of immunization and health
266 education for this population, given the history of rabies in Pará and the prevalent risk
267 factors for rabies [24].

268 Travassos da Rosa et al. (2006) stated that the proximity of animal husbandry to
269 the dwellings was a predisposing factor for the attacks on humans that occurred in
270 2004/2005 in Pará state. However, these characteristics were not observed in the present
271 study. For the population, RESEX's are associated to the improvement of the quality of
272 life of people that use forest resource for subsistence, being prohibited the creation of
273 livestock in these areas, because it contradicts its rules of sustainable use [22]. These units
274 were created for the protection of mangrove ecosystems, which constitute an area under

275 strong anthropic pressure, with increased exploitation of their natural resources [21].
276 Informal reports reveal that attacks on humans increased when bovine were removed from
277 such areas. It is also possible that hunting activities by the native population are promoting
278 a reduction in the supply of natural prey for bats, such as the crab-eating raccoon (*Procyon*
279 *carnivores*) and nonhuman primates. These animals are targeted and slaughtered by
280 fishermen because they feed on the crabs caught in their traps, thereby reducing their
281 daily catch. Another relevant factor is the fact that the vegetation of the area is
282 predominantly composed of natural fields and mangroves, where little food is available
283 for the vampire bat [20].

284 The age group most affected in this study differs from that reported in previous
285 studies. Whereas most of the victims in this study were male adults, Travassos da Rosa
286 et al. (2006) reported children as the main victims of the rabies virus transmitted by
287 vampire bats in the 2004-2005 period. In contrast to our study, the victims in the
288 Travassos da Rosa study were bitten in their own residences, which commonly house
289 families with individuals of various age groups. In this context, bats seem to prefer
290 children. In the present study, the targets of attacks were clusters of adults who gathered
291 for work, often associated with alcohol consumption. Individuals become passive and
292 docile victims after falling asleep following intense work activity during the day. This is
293 similar to the behavior of herd animals, which are favored targets of vampire bats, as they
294 seek abundant prey and tend to remain in the same place for prolonged periods to feed
295 [15,16].

296 This study also demonstrates for the first time the occupational nature of the bat
297 attack problem in the region. The vulnerability of crab fishermen is closely tied to their
298 work activity, as they are bitten primarily while working in the mangroves. Usually these
299 individuals dwell in shacks (huts) built on upland soil inside the mangrove or on the

300 beaches. These dwellings are completely open, with just a tarp or straw roof, and are used
301 for sleeping during the work period. Even students who were bitten reported that they
302 were accompanying their parents to help with crab fishing during the school vacation.

303 Residents of the Deolândia, Guarajuba and Porto Grande communities accounted
304 for most respondents. These communities are the main centers for swamp ghost crab
305 fishing in the region, and ghost crabs are the main natural resource exploited as a source
306 of income by these communities. Therefore, contact between humans and bats is
307 inevitable, as crabs are the only source of income for many of these fishermen. However,
308 the lack of individual protection equipment certainly contributes to the increased number
309 of bat attacks in this population [2,4].

310

311 **Conclusions**

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313 Using a single city as a model for investigating bat attacks in the Amazon, this study
314 showed that, for each person who seeks anti-rabies treatment after being attacked by bats
315 in the region, there are 12.2 people who do not seek care and can be easily reached by
316 surveillance agencies through snowball sampling. We also found that the population most
317 at risk is that of crab fishermen, suggesting that bat attacks are an occupational hazard.
318 These results can help health surveillance agencies to establish measures for the
319 prevention of human rabies in these individuals. They can also help minimize costs and
320 increase the efficiency of public health measures, thus avoiding the emergence of rabies
321 in the Salgado micro-region of Pará state.

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329

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407 **Figures Captions**

408

409 **Fig 1.** Study area. Distribution of extractive reserves in the Salgado microregion, Pará,
410 Brazil. The map was created specifically for this manuscript and was generated by ArcGis
411 10.1 (ESRI) based in Brazilian Institute of Geography and Statistic Database
412 (<https://downloads.ibge.gov.br/>)

413

414 **Fig 2.** Network of relationships between the residents of the São João da Ponta
415 municipality (Pará, Brazil) who were attacked by bats between 2013 and 2015. The nodes

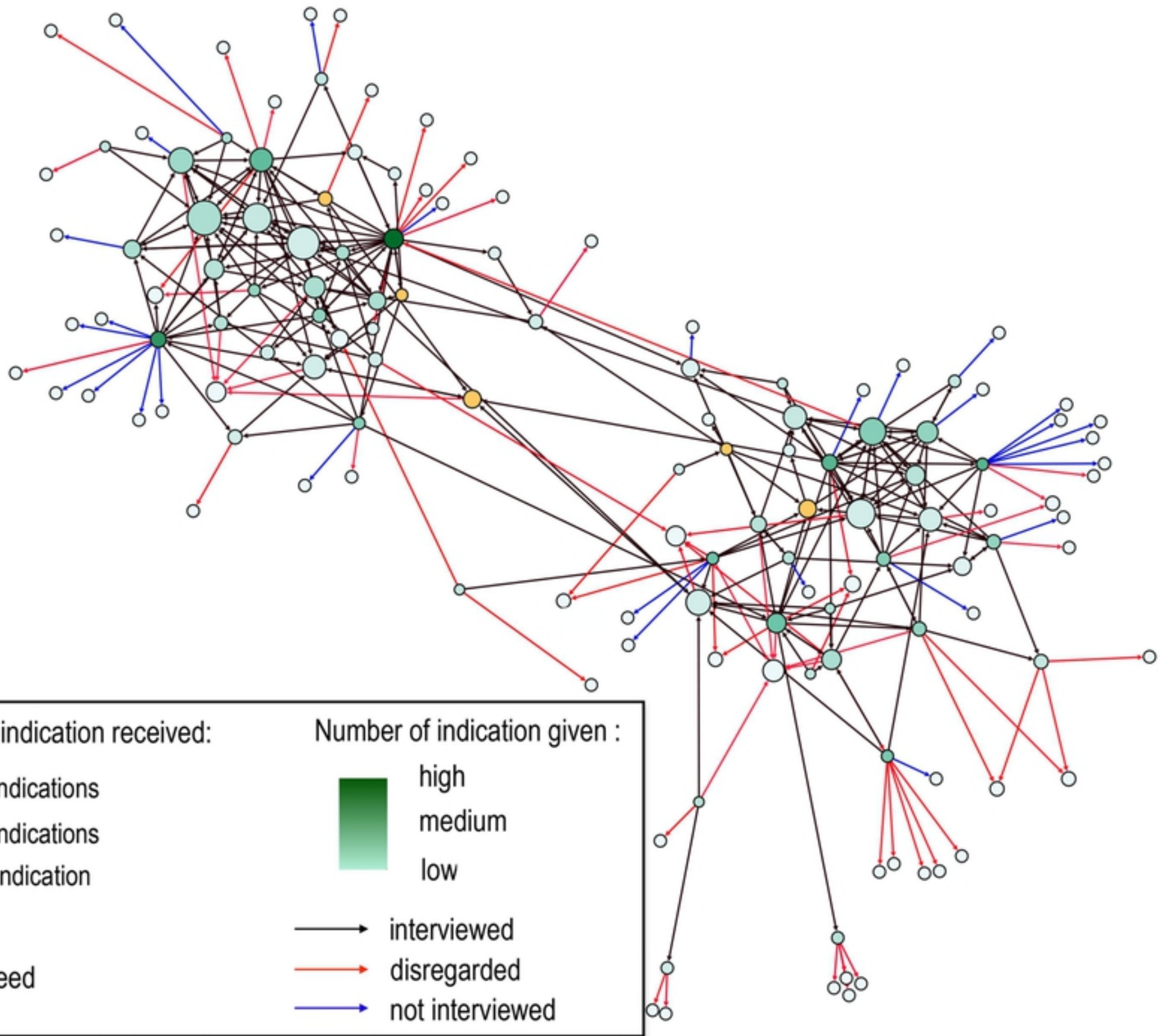
416 represent the individuals who were attacked. The diameter of the nodes is proportional to
417 the number of times the person was mentioned.

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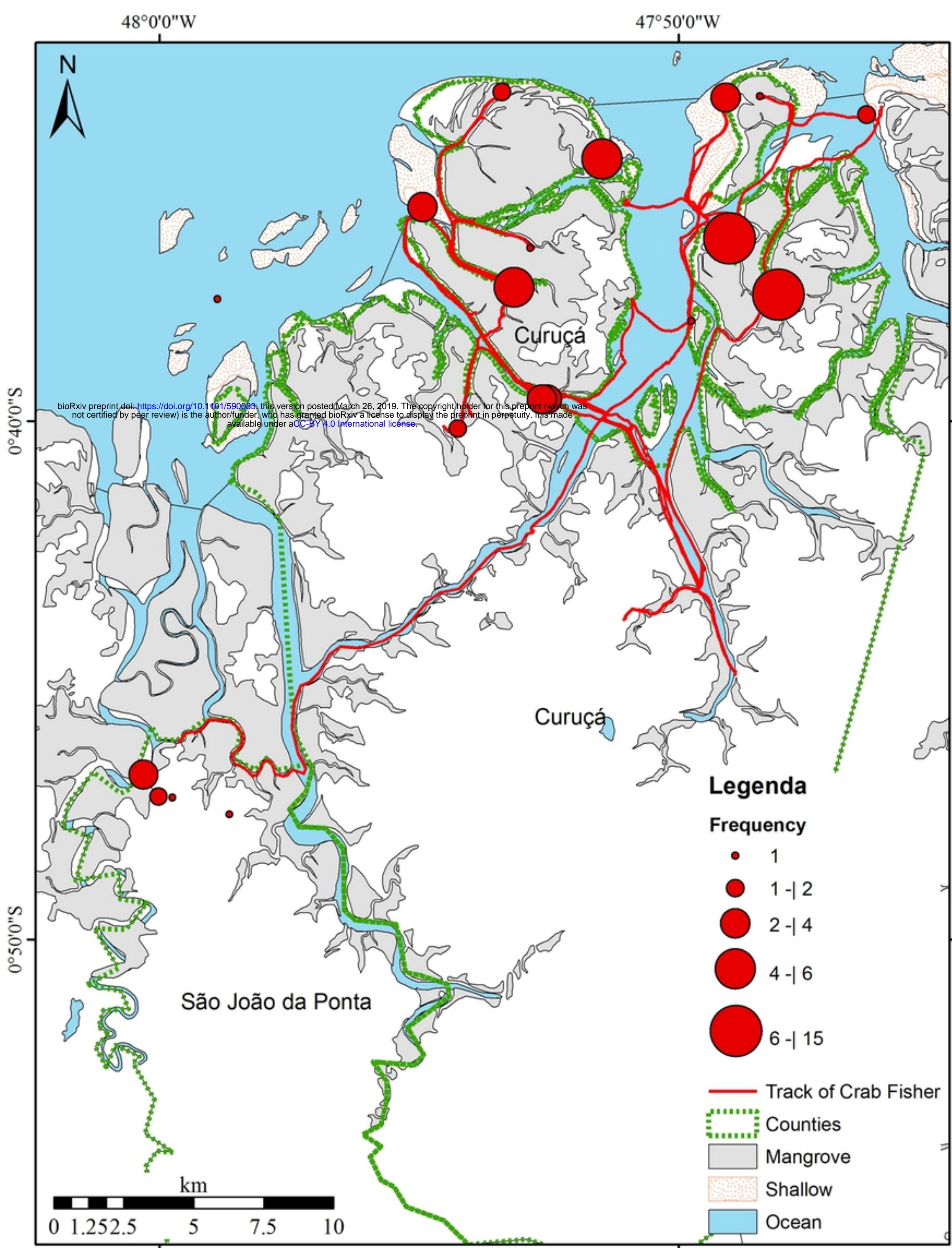
419 **Fig 3.** Spatial distribution of locations where residents of the Curuçá municipality were
420 attacked by bats. The lines indicate the route traveled by the crab fishermen from their
421 municipality of origin to the place where they camped for crab fishing. The map was
422 created specifically for this manuscript and was generated by ArcGis 10.1 (ESRI) based
423 in Brazilian Institute of Geography and Statistic Database
424 (<https://downloads.ibge.gov.br/>)

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426 **Fig 4.** Housing conditions of the individuals who were attacked. A) shack without walls
427 and with a straw roof; B) Shack without walls and with a tarp roof; C and D) Siriubeira.



Figure



Figure

A

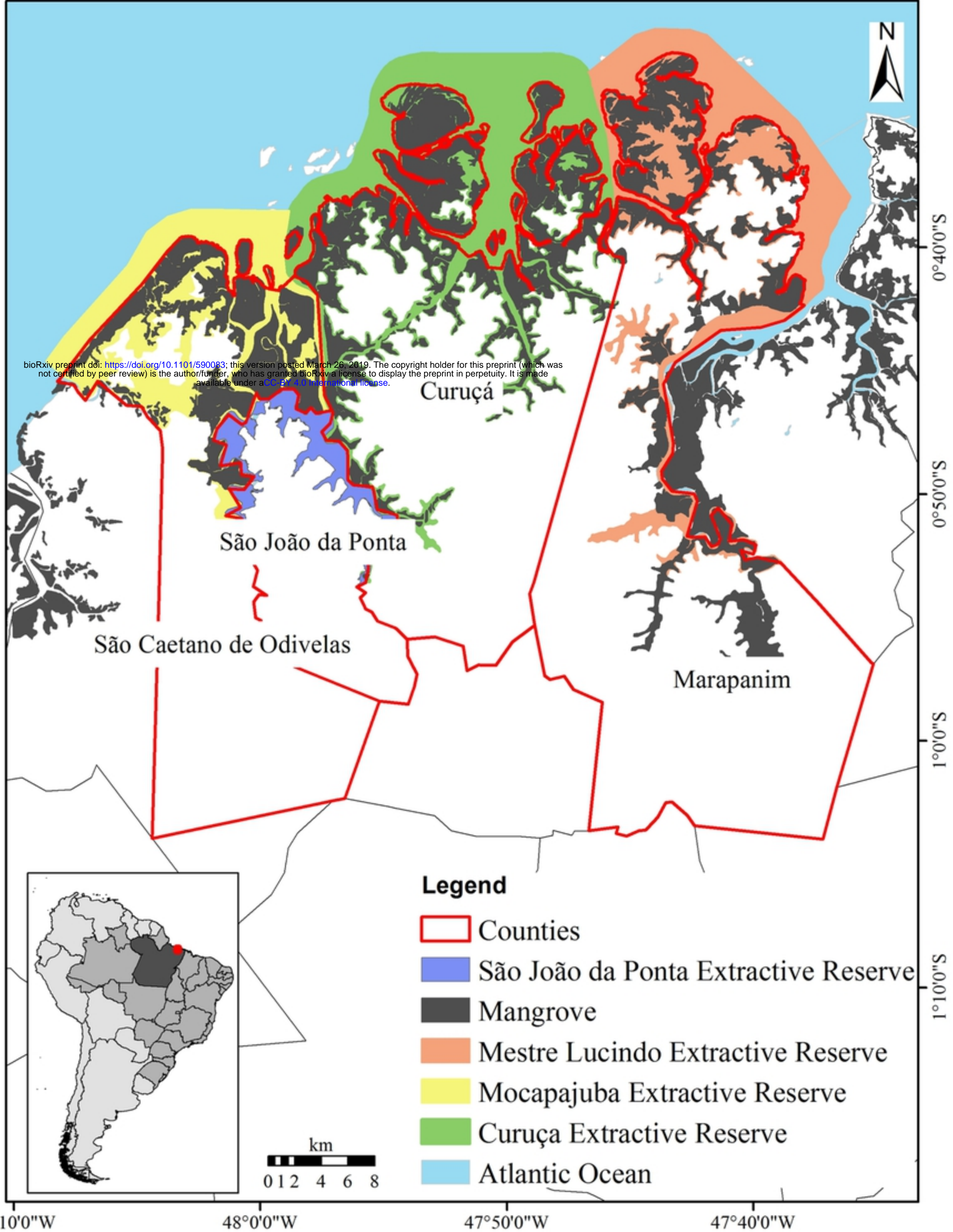
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B



Figure



Figure