

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

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### **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).

188

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



<b>How many people were at the scene of the aggression?</b>	More than five (63.3)	Two to five (24.1)	One (4.5)
<b>Was there any light source in place?</b>	Yes (87.9)	No (12.1)	-
<b>There is fresh water on site?</b>	Yes (59.1)	No (40.9)	-
<b>Where were you bitten??</b>	Beach (56.1)	Mangrove (30.3)	“Tiso” (3.0)
<b>In what circumstances have you been bitten?</b>	Fishing (83.1)	At leisure (6.2)	Others (6.2)
<b>At what time of year?</b>	Seca (54.5)	Chuvosa (45.5)	-
<b>FEATURES OF THE INJURY</b>			
<b>How many times have you been bitten in the last 3 years?</b>	One (33.3)	More than five (25.8)	Two (21.2)
<b>When was the last aggression?</b>	1 to 3 anos (37.9)	2 to 6 months (34.8)	7 months to 1 any (16.7)
<b>What was the amount of bites in the last attack?</b>	More than tree (45.5)	One (33.3)	Two (21.2)
<b>Type of Injury</b>	Single (71.2)	Multiple (28.8)	-
<b>Anatomical location of the wound</b>	Lower member (80.8)	Head (12.8)	Upper limb (5.13)
<b>Did you look for the health unit?</b>	No (86.4)	Yes (13.6)	-
<b>Do you believe that the bat bite causes any disease?</b>	Yes (80.3)	No (19.7)	-
<b>Do you know what rabies is?</b>	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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323

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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

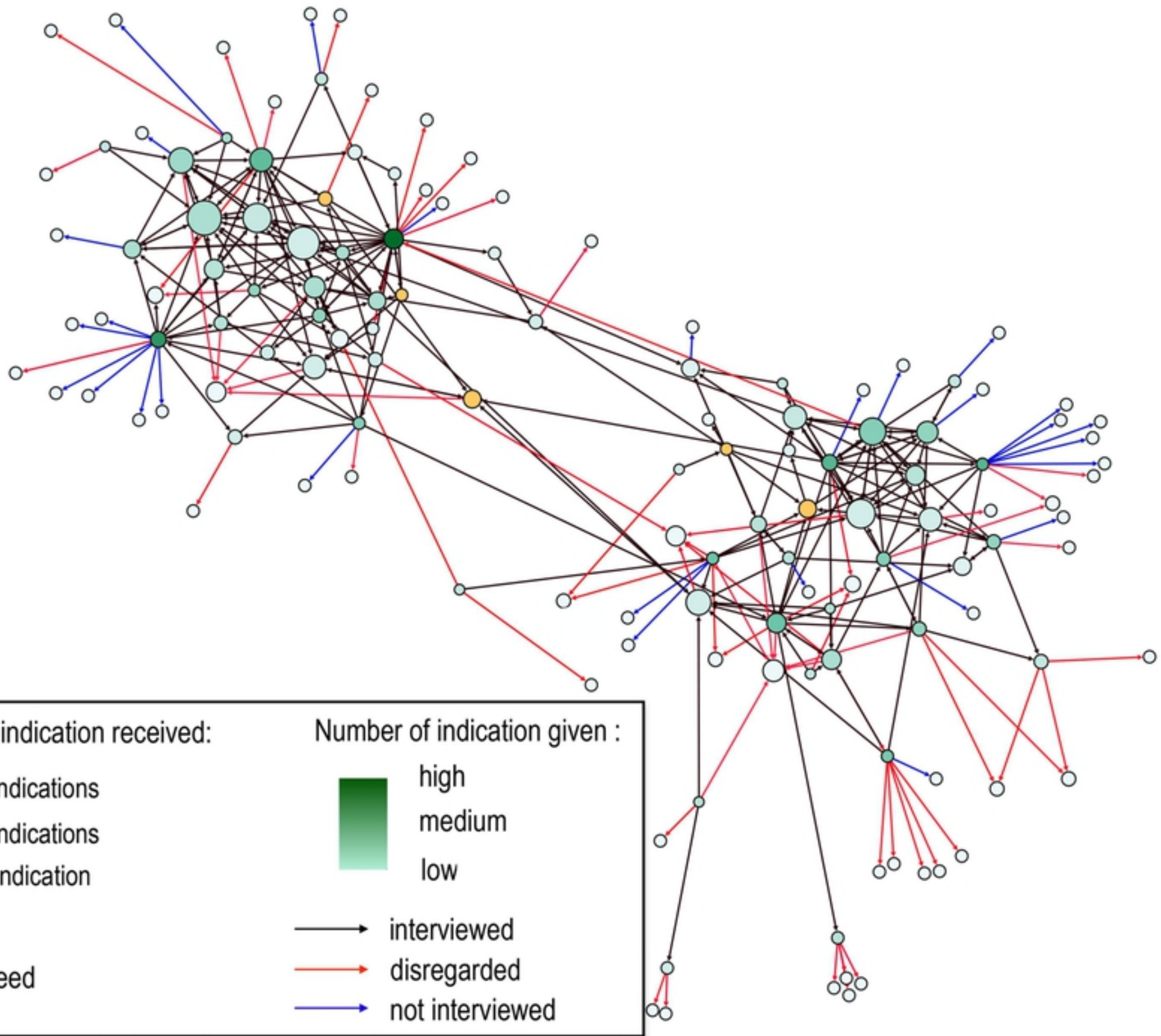
416 represent the individuals who were attacked. The diameter of the nodes is proportional to  
417 the number of times the person was mentioned.

418

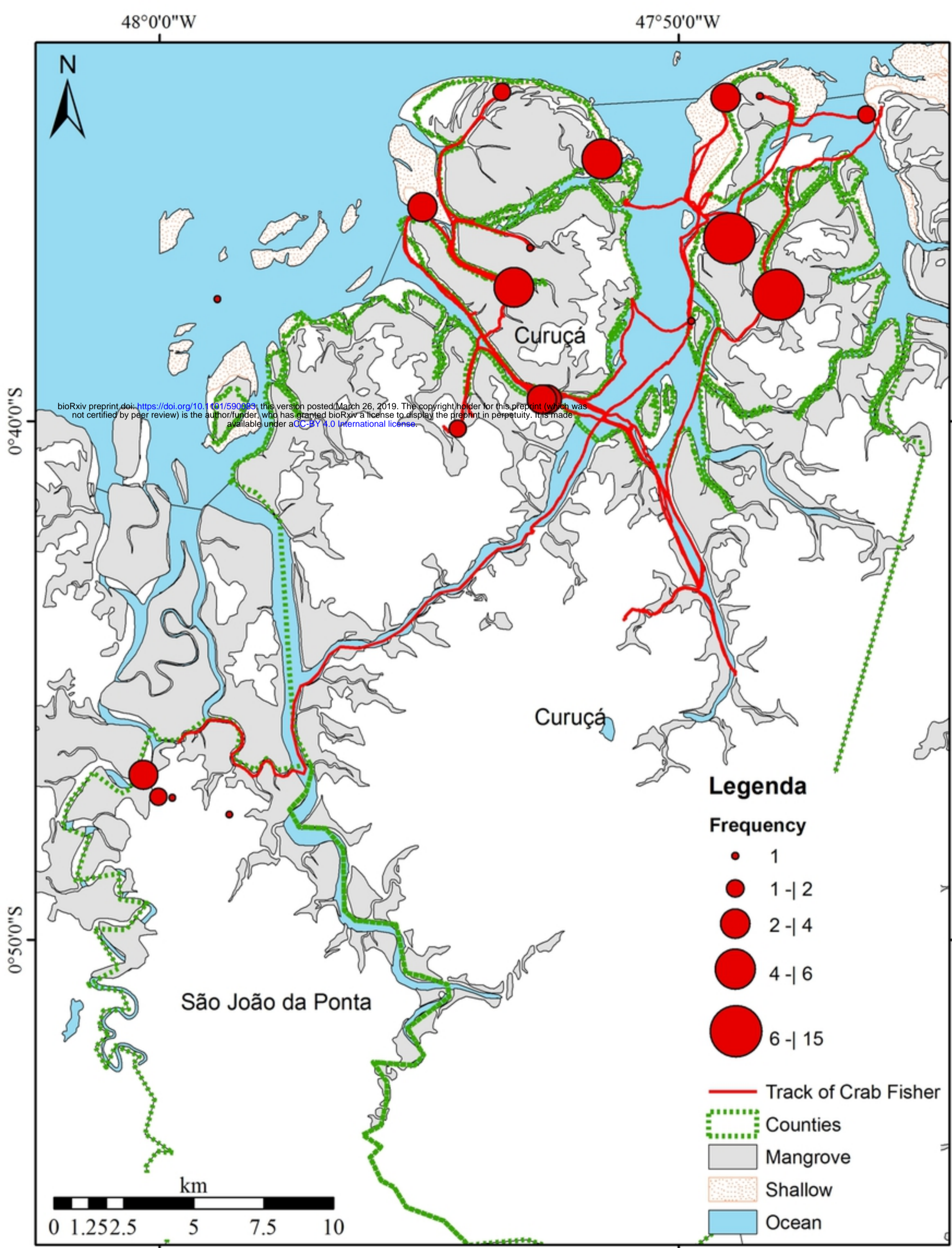
419 **Fig 3.** Spatial distribution of locations where residents of the Curuçá municipality were  
420 attacked by bats. The lines indicate the route traveled by the crab fishermen from their  
421 municipality of origin to the place where they camped for crab fishing. The map was  
422 created specifically 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

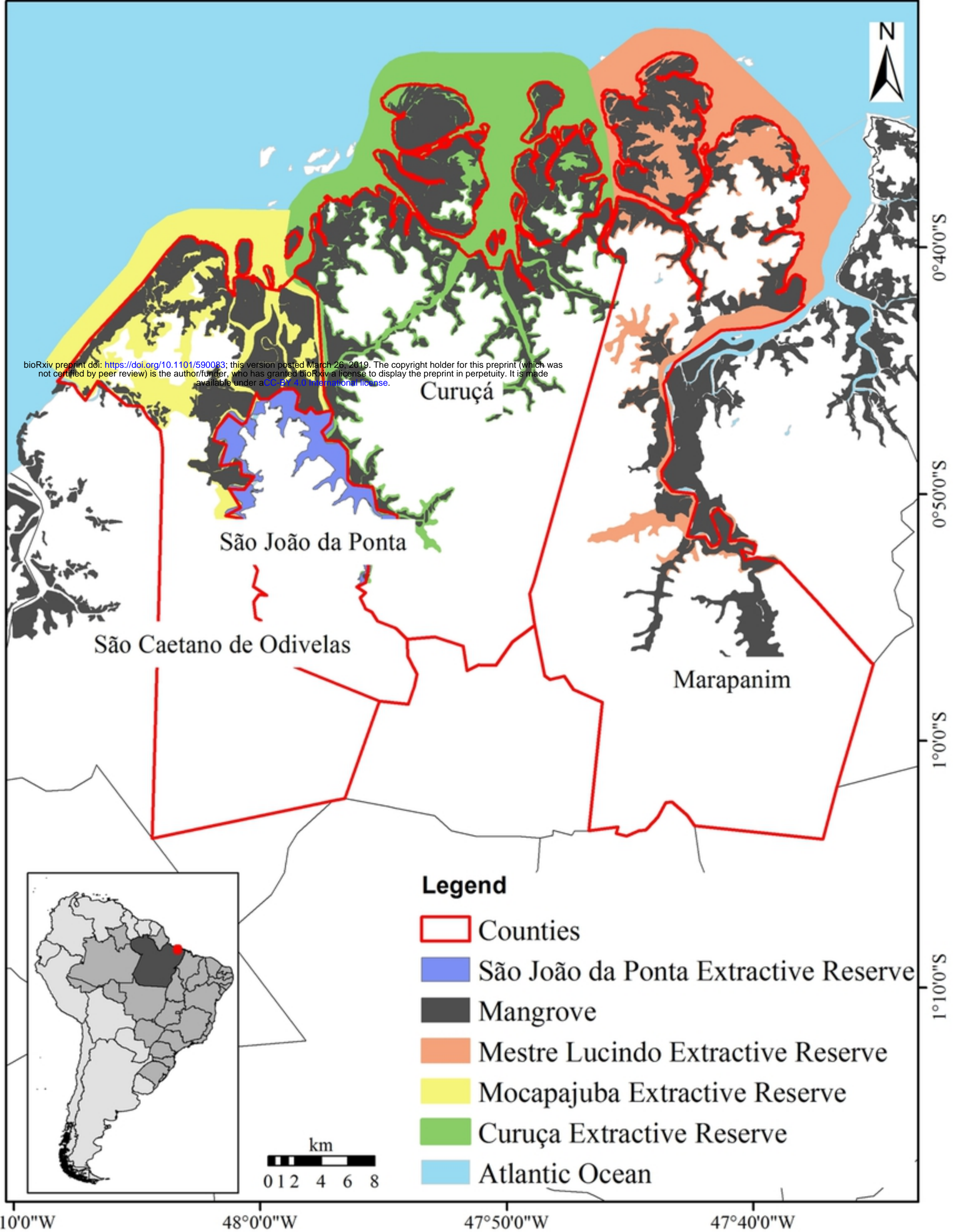
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B



Figure



Figure