

1 **Commercial relationships between intermediaries and harvesters of the mangrove**
2 **crab *Ucides cordatus* (Linnaeus, 1763) in the Mamanguape River estuary and their**
3 **socio-ecological implications**

4

5 Douglas Macêdo Nascimento^{a,*}, Rômulo Romeu Nóbrega Alves^b, Raynner Rilke Duarte
6 Barboza^b, Anders Jensen Schmidt^c, Karen Diele^{d,e}, José Silva Mourão^b

7

8 ^a Programa de Pós-Graduação em Etnobiologia e Conservação da Natureza,
9 Universidade Federal Rural de Pernambuco, Rua Dom Manoel de Medeiros, s/n, Dois
10 Irmãos - CEP: 52171-900 - Recife, PE, Brasil. ^b Departamento de Biologia,
11 Universidade Estadual da Paraíba, Av. Baraúnas, 351, Campus Universitário I,
12 Bodocongó - CEP: 58109-753 - Campina Grande, PB, Brasil. ^c Universidade Federal do
13 Sul da Bahia, Instituto de Humanidades, Artes e Ciências Paulo Freire, Praça Joana
14 Angélica, 250, São José - CEP: 45988-058 - Teixeira de Freitas, BA, Brasil. ^d School
15 of Applied Sciences, Edinburgh Napier University, Edinburgh, United Kingdom. ^e St
16 Abbs Marine Station, St Abbs, United Kingdom.

17

18 * Corresponding author.

19 E-mail address: douglasmacedo84@gmail.com (D.M. Nascimento).

20

21

22

23

24

25

26 Abstract

27 The large mangrove crab *Ucides cordatus* ("caranguejo-uçá") is a key fisheries resource
28 in Brazil, critical for the sustenance of livelihoods of thousands of people in coastal
29 rural areas. Today's crab populations suffer from habitat degradation, disease, and
30 increasing fishing pressure. Crabs are sold alive on local and regional markets, or traded
31 as processed meat and the market chains typically involve intermediaries (i.e. traders).
32 The present study examined the relationship between crab harvesters and the
33 intermediaries, and the socio-ecological implications thereof. The research was
34 performed between September 2013 and October 2014 in the Mamanguape River
35 estuary, northeastern Brazil. Socioeconomic information and data regarding the catch
36 (sex and carapace width of the crabs), the processing of *U. cordatus* meat and the
37 commercial relationship between harvesters and intermediaries were obtained through
38 structured (questionnaires) and semi-structured interviews and direct observations. The
39 crab harvesters exist under precarious socioeconomic conditions that place them at the
40 edge of society and therefore often seek loans offered by the intermediaries, generating
41 loyalty and dependence that guarantees the intermediaries a stable supply of crabs
42 needed to supply an avid market. Within this relationship, the intermediaries create
43 pressure on natural crab populations by stimulating non-selective captures, as they buy
44 specimens below the legal size limit (6 cm wide carapace) for processing. During crab
45 meat processing, the intermediaries themselves report that the crabmeat is often mixed
46 with cooked and shredded meat of marine vertebrates, such as spotted eagle ray
47 (*Aetobatus narinari*) and nurse shark (*Ginglymostoma cirratum*), to increase the weight
48 of the final product. As with the crab harvesters, the women involved in processing the
49 crabmeat often accept loans, resulting in the same type of dependence and loyalty to the
50 intermediaries. The intermediaries exercised a strong influence on crab harvesting and

51 are directly linked to the commercial, social and ecological implications of these
52 harvesting activities together with the crab harvesters themselves. Hence, to ensure
53 sustainability of the *U. cordatus* fishery and maintain (better improve) dependant
54 livelihoods, all actors involved in the production chain of *U. cordatus* must be
55 considered when developing management strategies, rather than the current approach of
56 considering the crab harvesters only. We advise the development and implementation of
57 fisheries associations to give the crab harvesters (and regulating bodies) greater control
58 over and capital gains from their catches.

59

60 **Key-words:** Production chain. Fishery. Sustainability. Conservation. Ethnozoology.

61

62 **1. Introduction**

63

64 The production chains of most artisanal fisheries around the world involve
65 intermediaries who have direct commercial contacts with the fishers acquiring their
66 catches and selling them to the final markets (Gibbon, 1997; Pasquotto, 2007; Platteau
67 and Abraham, 1987). Such commercial relationships have probably existed since the
68 dawn of commercial trade (Platteau and Abraham, 1987; Platteau and Nugent, 1992;
69 Merlijn, 1989; Russel, 1987).

70 Intermediaries represent a form of informal self-employment based on
71 reciprocity and verbal agreements with fishers. They can be itinerant, work
72 independently, and do not necessarily conform to legal directives, especially in terms of
73 taxes, worker legislation, or fishing regulations (Crona et al., 2010; Merlijn, 1989;
74 Platteau and Abraham, 1987). For the fishers, the key motivating factor for such
75 informal agreements is the buffering of the uncertain nature of production volumes

76 throughout the year (Wilson, 1980). In many developing countries, however, the
77 commercial ties between fishers and intermediaries result in a dependence and
78 reliability through accumulation of informal loans (Crona et al., 2010).

79 In addition to the economic and social implications, the fishers-intermediaries
80 relationship may also have considerable ecological implications, e.g. a direct influence
81 upon yield and size of the captured animals (Wilson, 1980). The ecological effects and
82 how these influence ecosystem services and health are however often understudied
83 (Crona et al., 2010).

84 In Brazil, the large mangrove crab *U. cordatus* ("caranguejo-uçá") is a key
85 fisheries resource critical for the sustenance of livelihoods of ten-thousands of people in
86 coastal rural areas (Alves and Nishida 2002, 2003; Alves et al., 2005; Nascimento et al.,
87 2012; Nishida et al., 2006; Glaser and Diele, 2004). These crabs live in burrows in the
88 mud up to 2 m deep and are harvested by so called "caranguejeiros" (mangrove crab
89 harvesters) who capture them with their hands, hooked sticks, or with traps, such as
90 tangle-netting (*redinha*) that are made from several loose polypropylene threads tied
91 together (Fig. 1), that are placed onto the entrance of the crab burrows, secured by
92 broken pieces of prop roots, to entangle and trap the animals when they emerge
93 (Nascimento et al., 2012). Crab harvesters are generally socio-economically
94 marginalized (Nordi et al., 2009), typically illiterate or functionally illiterate, and live in
95 very simple houses with little infrastructure under conditions of poor hygiene (Alves;
96 Nishida, 2003).

97 Despite the socioeconomic importance of *U. cordatus* in Brazil (Brazilian
98 Institute of the Environment and Natural Resources - IBAMA, 1995; Glaser, 2003;
99 Glaser and Diele, 2004; Kjerfve and Lacerda; Lacerda, 1993; Saint-Paul, 2006; Santos,
100 2002; Vieira et al., 2004; Wolff et al., 2000), especially in Paraíba State where the

101 present research was undertaken (Alves and Nishida, 2003; Alves et al., 2005;
102 Nascimento et al., 2011; Nascimento et al., 2012; Nordi et al., 2009), there are no
103 comprehensive studies focused on the commercialization of this species and the socio-
104 ecological implications of the relationships between the crab harvesters and
105 intermediaries.

106

107

108

109

110

111

112

113

114

115

116

117

118



119 **Fig. 1** – Crab harvester shredding polypropylene bags for making the tangle-nets (A)
120 and detail of a tangle-net manufacture in Tramataia community - PB (B). Photos:
121 Douglas Nascimento.

122

123 The present work was undertaken in an estuary in northeastern Brazil and
124 describes the steps in the processing (meat extraction) and commercialization of *U.*
125 *cordatus* and elucidates the social ecological effects associated with that production. As

126 such, the central question that oriented our study was: Do the intermediaries influence
127 how the crab harvesters exploit the mangrove crab *U. cordatus* and create socio-
128 ecological situations that threaten the sustainability of their harvests?

129

130 **2. Methods**

131

132 2.1. Study area

133

134 The study was undertaken in the indigenous village Tramataia, part of the
135 municipality Marcação, Paraíba State (PB), Northeastern Brazil. The village is situated
136 on the banks of the Mamanguape River estuary, the second largest in the State,
137 approximately 70 km north of the state capital of João Pessoa (06°43'02" – 06°51'54" S
138 - 35°07'46" - 34°54'04" W) (Fig. 2). The mangrove-fringed estuary is oriented in a
139 general East-West direction and is approximately 24 km long, with a maximum width
140 of 2,5 km at the coast.

141 The area of influence of the Mamanguape River estuary is included within the
142 Barra do Rio Mamanguape Environmental Protection Area – APA (Paludo and
143 Klonowisk, 1999). The mangrove forest, dominated by tree species such as *Rhizophora*
144 *mangle*, *Avicennia germinans*, *A. schaueriana* and *Laguncularia racemosa*, is one of the
145 best preserved in Paraíba State and is the second largest in that state, covering
146 approximately 45,65 km² (Sociedade Internacional para Ecossistemas de Manguezal -
147 ISME, 2005).

148

149

150

151

152

153

154

155

156

157

158



159

160

161

162

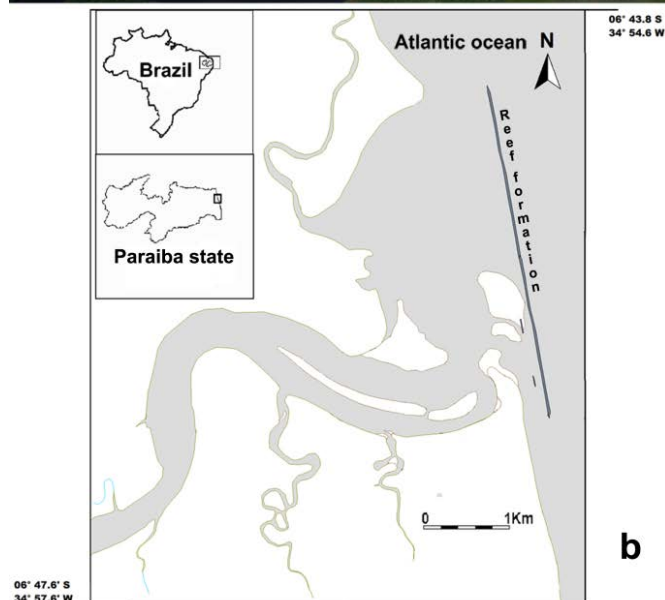
163

164

165

166

167



168 **Fig. 2** - The Mamanguape River estuary – PB, Brazil. A: Aerial view (Photo: Dirceu

169 Tortorello); B: Geo-referenced map (Figure adapted from Xavier et al. 2012).

170

171 The APA incorporates the Mamanguape, Miriri, and Estivas rivers, and some

172 small villages and agglomerations of houses within parts of the municipalities of Rio

173 Tinto, Marcação, and Lucena along the coast of Paraíba State (Paludo and Klonowisk,

174 1999).

175 Villagers of Tramataia (Potiguara ethnic group) regularly perform extractivist
176 activities in the Mamanguape River estuary, harvesting crustaceans, mollusks and fish.
177 The economically most important activity is harvesting of *U. cordatus* (Alves and
178 Nishida, 2003; Alves et al. 2005; Nascimento et al., 2011; Nascimento et al., 2012;
179 Paludo and Klonowski, 1999) (Fig. 3).

180

181

182

183

184

185

186

187

188



189 **Fig. 3** - Crab harvesters utilizing the braceamento technique to remove a mangrove crab
190 from its burrow in the Mamanguape River estuary - PB. (Photo: José Mourão).

191

192 Tramataia community has a total population of 1.110, of which 877 (452 men
193 and 425 women) are native Amerindians, comprising 243 families within 230
194 residences (SIASI - FUNASA/MS, 07/04/2011).

195

196 2.2. Research authorizations and methodological procedures

197

198 The Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio)
199 authorized scientific research in the APA Barra do Rio Mamanguape through the

200 System of Authorization and Information Concerning Biodiversity (SISBIO) (permit
201 numbers: 36974-1 and 36974-2). The Research Ethics Committee (CEP) of the
202 Universidade de Pernambuco (UPE) granted authorization for research with humans
203 (authorization number: 359.093). The Instituto de Patrimônio Histórico and Artístico
204 Nacional (IPHAN) granted authorization to investigate traditional knowledge without
205 access to genetic heritage (authorization number: 019/2014). Finally, the Fundação
206 Nacional do Índio (FUNAI) granted access to the indigenous lands of the Potiguara for
207 scientific research (authorization number: 97/AAEP/PRES/2014).

208 Crab harvesters and their intermediaries were interviewed between September
209 2013 and June 2014. The first interviewed crab harvesters had been indicated by the
210 president of the Z - 13 Fishing Colony at Tramataia; lateron crab harvesters were
211 selected via the "snowball" technique (Biernacki and Waldorf, 1981), in which
212 additional indications were provided by the initial interviewees. The intermediaries
213 interviewed were indicated by the crab harvesters themselves. The research involved
214 two data gathering techniques: 1) interviews, both structured and semi-structured
215 (Huntington, 2000) and 2) direct observations (Sttebins, 1987). The semi-structured
216 interviews with the crab harvesters (n = 106) and intermediaries (n = 5) contained pre-
217 formulated questions concerning the commercialization of *U. cordatus*; questions
218 concerning the processing of the crabmeat (processing steps) were addressed only to the
219 intermediaries. Structured interviews (questionnaires) with the crab harvesters were
220 conducted to gather basic information concerning their socioeconomic situations,
221 including their ages, sex, education, income, and housing and sanitary conditions.
222 Recordings of the interviews, which were previously authorized by the interviewees,
223 were made with a portable recorder and subsequently transcribed.

224 The direct observation technique, equivalent to the nonmember participant
225 observer technique (Sttebins, 1987), was used in to describe aspects of the crab
226 commercialization, such as the storage of yields in crab harvester residences and the
227 processing of the crabmeat.

228 The final price of the crabs in the supply chain was verified by information
229 gathered from 31 pub and restaurant owners in the municipality of João Pessoa, Paraíba
230 State - PB, the principal destination of the production of *U. cordatus* from the
231 Mamanguape River estuary.

232 The specimens captured by the crab harvesters during 74 harvesting trips
233 between September 2013 and October 2014 were analyzed in terms of their sex and
234 carapace width – CW (transversal measurement of the carapace at its widest point). The
235 sexes of the specimens were determined based on the shape of the abdomen, this
236 structure being triangular in males and rounded in females. The CW (largest body
237 dimension) was measured using a digital caliper (precision 0.01 mm).

238

239 2.3. Data analysis

240

241 Qualitatively, the data analyses followed an emic/etic approach (Toledo, 1991).
242 Emic approaches consider the manners in which the members of a given culture
243 perceive, structure, classify, and articulate their universe, while an etic approach
244 considers how the researcher views that universe as an outside observer (Posey, 1987).
245 Quantitatively, the carapace width data (CW) of the *U. cordatus* specimens (maximum,
246 minimum, median, and standard error) were analyzed using Excel 2007 software.

247

248 3. RESULTS

249

250 3.1. Socio-economic profiles of the crab harvesters and dependency on *U. cordatus*

251

252 All of the crab harvesters interviewed in Tramataia village were men (n = 106),
253 with ages ranging from 15 to 62 years (median 36). The majority were literate 63.2% (n
254 = 67) or semi-literate 25.5% (n = 27), with only 11.3% (n = 12) being illiterate. The
255 interviewees that had sons or daughters (74.5%; n = 79) stated that all of them attended
256 school, while 25.5% (n = 27) had no children or their children did not attend school.

257 In terms of habitation, all of the interviewees were homeowners, having built
258 them around the perimeter of the mangrove swamp. The houses were of two types:
259 bricks with ceramic roof tiles (60.4%; n = 64); or mud and wattle with ceramic roof tiles
260 (39.6%; n = 42). The crab harvester households consisted of a median of 5.2 individual
261 per habitation, with the majority of the households (71.7%; n = 76) having a monthly
262 income of one minimum Brazilian wage [US\$ 253,55/1 dollar (USD) = R\$ 3,47 reais
263 (BRL). Quotation, June 14, 2016)], while 28.3% (n = 30) reported incomes of up to two
264 minimum wages. Among these households, 44.5% (n = 42) of all households were
265 included in federal government assistance programs (such as *Bolsa Família*).

266 All interviewed crab harvesters stated that capture of *U. cordatus* was their
267 principal activity and main income source, however 58.5% (n = 62) of the interviewees
268 stated that they caught fish also. Most crab harvesters (86.8%; n = 92) were dissatisfied
269 with the infrastructure of the community where they lived, including its sanitary
270 deficiencies.

271

272 3.2. Commercialization

273

274 Individual crab harvesters reported that they maintained a commercial
275 relationship with one of the five intermediaries active in the region. All intermediaries
276 were men. Most of the harvesters (85%) capture crabs five days in the week, and their
277 accumulated production is collected at their houses by the traders (intermediaries),
278 normally twice a week (Wednesday and Friday).

279 Tramataia crab harvesters store the crabs loose in polypropylene sacks until they
280 are sold (Fig. 4). The intermediaries collect the crab lots within relatively short time
281 intervals to avoid excessive mortality after capture, especially in light of their extremely
282 poor storage conditions.



283
284
285
286
287
288
289
290
291
292
293 **Fig. 4** - Live crabs stored in polypropylene sacks at the Mamanguape River estuary,
294 Paraíba State, Brazil. Photo: Douglas Nascimento.

295
296 The basic sales unit of mangrove crabs is a “*corda*” consisting of a dozen crabs.
297 The price of a dozen crabs which is previously agreed on by both parties, varies from
298 US\$ 0.72 to US\$ 1.44 in 2014. A *corda* composed of large male crabs (carapace width

299 of 6 cm or above) has the greatest commercial value, while a mixed *corda* (small males
 300 and females of varying sizes) will be traded for less. Most of the crab harvesters
 301 (87.3%) reported that they preferred to receive payment only once a week, on Fridays,
 302 arguing that this arrangement is more convenient to both parts.

303 After acquiring the crabs from the harvesters, the intermediaries separate them
 304 according to size and sex. Large males (≥ 6 cm) are sold alive to the final buyers, while
 305 the smaller males and females are primarily processed for their meat. The production
 306 chain is outlined in figure 5.

307

308

309

310

311

312

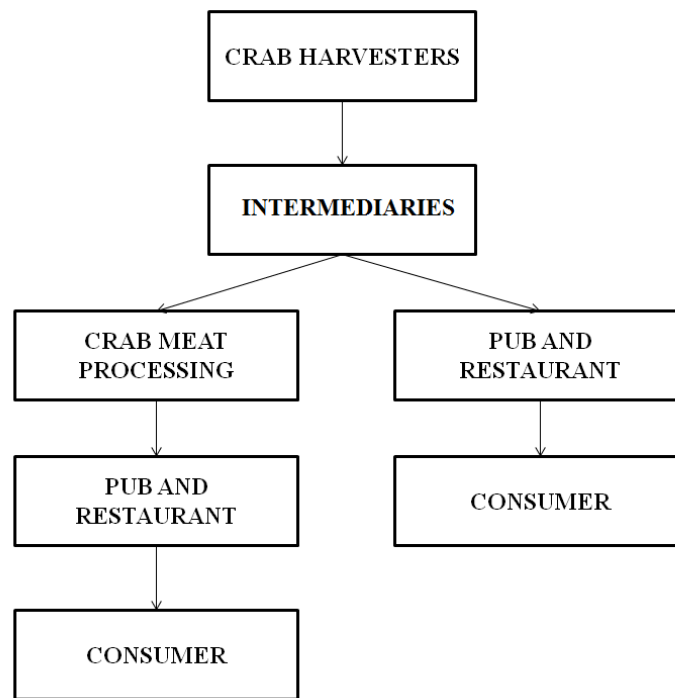
313

314

315

316

317



318 **Fig. 5** – Production chain of *U. cordatus* harvesting in the Mamanguape River estuary –
 319 PB.

320 According to the intermediaries, the principal markets for *U. cordatus* (live
 321 specimens and their meat) are pubs and restaurants in large northeastern Brazilian cities
 322 such as João Pessoa, Campina Grande, Natal and Recife. The intermediaries informed
 323 that without demand from those pubs and restaurants, crab harvesting would not be

324 economically rewarding, as they absorb almost all production. The pub and restaurant
325 owners in the city of João Pessoa (the principal commercial destination) purchase a
326 dozen live crabs for US\$ 7.20. The clients of those bars and restaurants will then pay
327 from US\$ 1.41 to US\$ 2.59 for a single crab, with an average price of US\$ 1.64.

328 The intermediaries maintain commercial infrastructures necessary for selling
329 their products, consisting of (at least) transportation (an automobile) and polystyrene
330 boxes to hold the crabs. In addition they bear operating costs to cover expenses for fuel,
331 food, and daily wages for helpers to load and unload the merchandise. Most of the crab
332 harvesters (94%) stated that they did not have access to such infrastructure, principally
333 transport, but also money for the operational expenses, making it impossible to
334 complete the later stages of commercialization. Additionally, 65% of the crab harvesters
335 stated that they did not have the ability to commercialize their catches on their own,
336 preferring to dedicate themselves only to harvesting – which does not leave sufficient
337 time to carry out other activities.

338 The crab harvesters and intermediaries maintain a dependence within a “worker
339 and boss” model. Confidence is established by the intermediaries by conceding favors to
340 the crab harvesters. All intermediaries interviewed reported that they provide informal
341 loans to the crab harvesters based on personal confidence - without any written
342 document or interest charges. The loans were largely furnished to provide for the basic
343 necessities of the crab harvesters in exchange for guaranteeing exclusive rights to their
344 harvests.

345 All crab harvesters indicated that they feel exploited by the intermediaries due
346 to the considerable physical effort required to capture the crabs and the low prices
347 offered to them in return. However, this dissatisfaction is not externalized in their
348 relationships with the intermediaries and in some cases they often establish bonds of

349 considerable friendship with the intermediaries - with the latter occasionally becoming
 350 godparents to their sons and daughters.

351

352 3.3. Crab meat processing

353

354 Of the 8755 crabs captured by the crab harvesters during the course of the
 355 research project, 26.8% (n = 2346) were below the legal size limit (60 mm) and were
 356 consequently processed for meat extraction (1.357 males [15.5%] and 989 females
 357 [11.3%]). The maximum and minimum carapace widths (CW) of these crabs for
 358 processing were 59.97 mm and 50.78 mm, with a mean of 57.57 mm (standard error =
 359 1.978, Table 1).

360

361 **Table 1** Carapace widths (CW) of the mangrove crabs processed for their meat in the
 362 Mamanguape River estuary, Paraíba State, Brazil.

	VALUES (mm)	CW
	Maximum	59.96
Males	Minimum	50.78
(n = 1357 crabs)	Mean	57.65 (\pm 1.929)
	VALUES (mm)	CW
	Maximum	59.97
Females	Minimum	51.41
(n = 989 crabs)	Mean	57.46 (\pm 2.037)

363

364 The processing activities of *U. cordatus* crab meat are managed (and in part
 365 performed) by the intermediaries in the municipality of Marcação on a year-round basis.

366 The process is composed of four steps: a) cooking the crabs; b) dismembering them; c)
367 washing the dismembered parts; and d) extracting the meat (Fig. 6). Remaining crab
368 parts are not used for any other purpose and are discarded in the open air.



379 **Fig. 6** - Steps in the processing of *U. cordatus* meat at the Mamanguape River estuary,
380 Paraíba State, Brazil: a) cooking the crabs; b) dismembering the crabs; c) washing the
381 pereiopods; and d) extracting the meat. Photos: Douglas Nascimento.

382

383 The place where the crabs are processed for their meat is called a “*coapa*”, and
384 is provided with a rustic wood-burning stove built by the intermediaries in their own
385 backyards. The intermediaries (with the help of their family) immerse the live crabs into
386 boiling water inside large aluminum cauldrons, and left to cook for approximately 30
387 min; after cooking, the ventral section and the pereiopods (including the chelipeds) are
388 dismembered and washed (Fig. 7). The intermediaries then deliver these parts to women
389 living in the community who they have hired to extract the meat. Extraction itself is
390 performed using a small knife (15 cm long), locally known as a *pinça*. The women are

391 paid US\$ 1.15 for each kilogram of extracted meat. Each woman can extract a
392 maximum of 4 kg per day, and can therefore earn up to US\$ 4.61/day. Due to the low
393 earnings, the women often take out small loans with the intermediaries, thereby
394 generating dependence and loyalty to them, much in the same way as the crab
395 harvesters.

396

397

398

399

400

401

402

403

404

405

406

407

408

409



410 **Fig. 7** – A: *Coapa* - Typical processing site of specimens of *U. cordatus* crabs in the
411 Mamanguape River estuary, Paraíba State, Brazil; B: Separated parts of mangrove
412 crabs: ventral portion (left) and pereiopods (right). Photos: Douglas Nascimento.

413

414 The processed crabmeat is presented to the intermediaries, who then weigh the
415 yields, place them in plastic sacks holding 1 kg, and subsequently store them in a

416 freezer, where they will be maintained until further transport. There are two distinct
417 prices for processed crabmeat: meat extracted from the ventral region of the crab and
418 the pereopods is sold for US\$ 5.76/kg, while meat extracted from the chelas is more
419 valuable and is sold for US\$ 10.08/kg. The intermediaries themselves report, however,
420 that the crabmeat is often mixed with cooked and shredded meat of marine vertebrate.
421 The most commonly used two local species of elasmobranches: the spotted eagle ray
422 *Aetobatus narinari* (Euphrasen, 1790) and the nurse shark *Ginglymostoma cirratum*
423 (Bonnaterre, 1788). Ray meat, which has less value on the local market (averaging US\$
424 1.01) but is more abundant than nurse shark meat, is more frequently utilized for
425 adulterating the crabmeat. This adulteration is performed to increase profits. According
426 to the intermediaries, this “fake” crab meat can represent more than half of the “crab”
427 sold commercially.

428

429 **4. Discussion**

430

431 The entire production of the crab harvesters in the research area is readily
432 acquired by intermediaries to supply a high-demand market in nearby cities. Within this
433 context, the intermediaries establish informal agreements of credit and reciprocity,
434 generating dependence and fidelity with crab harvesters. A similar situation was
435 reported by Reis (2007) in Bragança, Pará State, Brazil. Various authors have noted that
436 the credit offered to the artisanal fishers is a way of guaranteeing priority access to their
437 catches, thus guaranteeing continuous and stable stocks (Platteau and Abraham, 1987;
438 Russel, 1987; Merlijn, 1989) - although this has a strong effect on the social resilience
439 of the fishers (Platteau and Abraham, 1987) who are generally very poor and have had
440 little formal education (Madduppa et al., 2014). Our results reinforce these observations,

441 revealing the persistence of socioeconomic situations similar to those reported by Alves
442 and Nishida (2002). This recurrent situation reflects the strong dependence of crab
443 harvesters on the intermediaries.

444 The practice of informal loans (which causes as well as reinforces loyalty and
445 dependence, and suggests exploitation of the crab harvesters) has been observed among
446 artisanal fishers and their intermediaries in other parts of the world, as reported by
447 Ochiewo et al. (2010) in Kenya, Madduppa et al. (2014) in Indonesia, Merlijn (1989) in
448 Malaysia, and Rahman et al. (2013) in Bangladesh. These situations of informal loans
449 generally do not involve interest payments or any explicit payment deadline (Platteau
450 and Abraham, 1987; Platteau and Nugent, 1992; Merlijn, 1989), being based
451 exclusively on mutual confidence (Crona, 2010), as observed in the present work.

452 The relationships of dependence of the crab harvesters with intermediaries also
453 involves the marketing of their harvests. The intermediaries provide secure and rapid
454 sales, guaranteeing the purchase of their harvests in the crab harvesters own homes -
455 which allows them to invest their time solely in harvesting activities. However, within
456 this production chain, and due to the low prices that the crab harvesters obtain for their
457 products, they must invest even greater efforts in harvesting activities if they wish to
458 increase production and thus increase their income. More intense harvesting efforts, of
459 course, imply greater pressure on natural populations of these mangrove crabs.

460 The links that *U. cordatus* harvesters have to intermediaries influence the type of
461 exploitation of this natural resource, and drive cultural changes as to how they capture
462 their prey (Alves and Nishida, 2003). The quest for greater productivity (to improve
463 their low incomes), for example, has led to the wide adoption of a more efficient
464 harvesting techniques involving the use of “tangle-netting” (Nascimento et al., 2016),
465 which, according to Nascimento et al. (2011) has caused a cultural rupture leading to the

466 disuse of traditional capture techniques in the Mamanguape River estuary. The potential
467 environmental impacts related to the utilization of this new capture technique include:
468 less selective harvests (crab sizes and sexes), increased production, pollution (through
469 plastic strings remaining in the mangrove), and the mutilation of the prop roots of *R.*
470 *mangle* to help fix the tangle-netting above the burrow entrances (Nascimento et al.,
471 2012).

472 The less selective capture with tangle-netting practiced by the crab harvesters
473 (Nascimento et al., 2016) appears to be the consequence of the close relationships
474 between the actors involved in crab harvesting. The intermediaries use both male and
475 female specimens of *U. cordatus* with carapace widths <6 cm for crab meat processing,
476 which conflicts with the federal legislation (Decree IBAMA/PB n.º 34 of 03 June,
477 2003). The capture of small individuals can result in growth and recruitment overfishing
478 and potentially reduce *U. cordatus* populations that are slow growing (Fiscarelli and
479 Pinheiro, 2002; Diele et al., 2010).

480 Another ecological implication of the crab meat processing consists of the use of
481 other marine species in the production chain of *U. cordatus* exploitation, such as
482 *Ginglymostoma cirratum*, which appears on the List of Animals Threatened with
483 Extinction under the vulnerable category (Portarias MMA nº 444/2014 and nº
484 445/2014). The incorporation of the meat of this species into products being sold as *U.*
485 *cordatus* is a form of camouflaging the utilization and exploitation of a threatened
486 species.

487 The social and economic dependence of the artisanal fishers in relation to the
488 intermediaries may impact the sustainable use of marine resources (Crona et al., 2010).
489 Additionally, there is a risk that any potential non-sustainability of long-term crab
490 harvesting could be masked by production levels artificially maintained by

491 technological improvements (Ludwig et al., 1993; Pauly et al., 2002), obscuring
492 possible declines in stock levels (Capistrano and Lopes, 2012).

493

494 **5. Final considerations**

495

496 Our results indicate that the principal actors involved in the production chain of
497 *U. cordatus* (intermediaries and crab harvesters) must be considered when
498 contemplating strategies for the sustainable management of this species – and not just
499 the crab harvesters, who have heretofore been the sole focus of management plans
500 developed by Brazilian environmental organs. Given the strong influence of
501 intermediaries on the crab harvesting and commercialization process, these actors, as
502 much as the crab harvesters themselves, are key drivers of social, economic, and
503 ecological effects of this artisanal fishery.

504 Within this framework, we recommend that crab harvesters and the women
505 involved in processing the crabmeat should organize themselves into cooperatives or
506 associations, that could strengthen their social organization and create new forms of
507 managing their harvests, generating alternatives for direct commercialization of their
508 products. If there is interest from the intermediaries, they could also be part of the same
509 cooperatives or associations. These professionals have experience with the dynamics of
510 the market and a network of contacts previously established, which is useful in an
511 organization of cooperative or association type. In this case, the intermediaries could
512 become sales representatives (dealers).

513 The organization of cooperatives and associations would aggregate value to their
514 products, guaranteeing greater economic profit for the crab harvesters. To do that,
515 however, it will be necessary to establish links with public and/or private institutions

516 (e.g. environmental organizations, universities, research institutes, non-governmental
517 organizations) to provide infrastructure for storage and transport, as well as educational
518 courses for crab harvesters in trading and basic economy. These partnerships could, for
519 example, contribute to the dissemination of techniques guaranteeing the final quality of
520 the processed crab meat; it should also be possible to develop further use of crab
521 residues resulting from meat processing, such as organic fertilizer and animal rations,
522 instead of simply discarding these by-products.

523 Additionally, the organization of crab harvesters into cooperatives would
524 facilitate the monitoring of their catches by environmental organs, as the cooperative
525 would be required to maintain registers of the quantities and sizes of the specimens
526 captured, which would significantly aid in maintaining healthy natural stocks.

527

528 **Author contributions**

529

530 DMN participated in all of the research steps. RRNA, RRD and JSM contributed
531 to the design of the work and data analysis. AJS e KD contributed to the data analysis of
532 the work. All authors were involved in manuscript preparation and have read and
533 approved the final version.

534

535 **Conflicts of interest**

536

537 The authors declare that there were no conflicts of interests related to this work,
538 and it has not been submitted to other journals for publication.

539

540 **Acknowledgments**

541

542 The authors would like to thank the inhabitants of the Tramataia village,
543 especially the crab harvesters, who kindly shared their valuable knowledge with us; the
544 *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)* for awarding
545 a study grant to the first author; and the administrators of the Barra do Rio Mamanguape
546 Environmental Protection Area for their hospitality and housing in Barra de
547 Mamanguape – PB during the data collection activities. Karen Diele received funding
548 from the MASTS pooling initiative (The Marine Alliance for Science and Technology
549 for Scotland) and its support is gratefully acknowledged. MASTS is funded by the
550 Scottish Funding Council (grant reference HR09011) and contributing institutions.

551

552 REFERENCES

553

554 Alves, R.R.N., Nishida, A.K., 2002. A ecdise do caranguejo-uçá, *Ucides cordatus* L.
555 (DECAPODA, BRACHYURA) na visão dos caranguejeiros. *Interciência* 27, 110-117.

556

557 Alves R.R.N., Nishida A.K, 2003. Aspectos socioeconômicos e percepção ambiental
558 dos catadores de caranguejo-uçá, *Ucides cordatus cordatus* (L. 1763) (Decapoda,
559 Brachyura), no estuário do Rio Mamanguape, Nordeste do Brasil. *Interciencia* 28: 36-
560 43.

561

562 Alves, R.R.N., Nishida, A.K., Hernandez, M.I.M., 2005. Environmental Perception of
563 Gatherers of the Crab Caranguejo-uçá (*Ucides cordatus*, Decapoda, Brachyura)
564 Affecting Their Collection Attitudes. *J. Ethnobiol. Ethnomed.* 1, 1-8.

565

- 566 Biernarcki, P., Waldorf, D., 1981. Snowball sampling problems and techniques of chain
567 referral sampling. *Sociological Methods and Research* 10, 141-163.
- 568
- 569 Brazilian Institute of the Environment and Natural Resources – IBAMA, 1995. Os
570 ecossistemas brasileiros e os principais macrovetores de desenvolvimento: subsídios ao
571 planejamento da gestão ambiental. Ministério do Meio Ambiente, Recursos Hídricos e
572 da Amazônia Legal, Programa Nacional do Meio Ambiente -PNMA. MMA, Brasília.
- 573
- 574 Capistrano, J.F., Lopes, P.F.M., 2012. Crab gatherers perceive concrete changes in the
575 life history traits of *Ucides cordatus* (Linnaeus, 1763), but overestimate their past and
576 current catches. *Ethnobiol. Conserv.* 1, 1 – 21.
- 577
- 578 Crona, B.; Nyström, M.; Folke, C.; Jiddawi, N., 2010. Intermediaries, a critical social-
579 ecological link in coastal communities of Kenya and Zanzibar. *Marine Policy* 34, 761-
580 771.
- 581
- 582 Diele, K., Koch, V., 2010. Growth and mortality of the exploited mangrove crab *Ucides*
583 *cordatus* (Ucididae) in N-Brazil. *Journal of Experimental Marine Biology and Ecology*
584 395, 171-180.
- 585
- 586 Diele, K., Araújo, A.R., Glaser, M., Salzmann, U., 2010. Fishery of the mangrove crab
587 *Ucides cordatus* in N-Brazil: First steps to successful co-management. In: Saint-Paul,
588 U., Schneider, H. (Eds.), *Mangrove Dynamics and Management in North Brazil*
589 *Ecological Studies* Vol. 211. Springer, Berlin-Heidelberg, pp. 287–297.
- 590

591 Fiscarelli, A.G., Pinheiro, M.A.A., 2002. Perfil sócio-econômico e conhecimento
592 etnobiológico do catador de caranguejo-uçá, *Ucides cordatus* (Linnaeus, 1763), nos
593 manguezais de Iguape (24° 41'S), SP, Brasil. *Actualidades Biológicas* 24, 129-142.

594

595 Gibbon, P, 1997. Prawns and piranhas: the political economy of a Tanzanian private
596 sector marketing chain. *Journal of Peasant Studies* 25, 1–86.

597

598 Glaser, M, 2003. Interrelations between mangrove ecosystem, local economy and social
599 sustainability in Caeté Estuary, North Brazil. *Wetlands Ecology and Management* 11,
600 265 – 272.

601

602 Glaser, M., Diele, K, 2004. Asymmetric outcomes: assessing central aspects of the
603 biological, economic and social sustainability of a mangrove crab fishery, *Ucides*
604 *cordatus* (Ocypodidae), in North Brazil. *Ecological Economics* 49, 361 – 373.

605

606 Huntington, H.P, 2000. Using traditional ecological knowledge in science: methods and
607 applications. *Ecol Appl* 10, 1270-1274.

608

609 Kjerfve, B., Lacerda, L. D., 1993. Management and status of the mangroves of Brazil.
610 In: ISME/ ITTO, Conservation and Sustainable utilization of mangrove forests in Latin
611 America and Africa regions. Part I Latin Ameri, p. 245–272.

612

613 Ludwig, D., Hillborn, R., Walters, C., 1993. Uncertainty, resource exploitation, and
614 conservation: lessons from history. *Science* 260, 17-36.

615

- 616 Madduppa, H.H., Juterzenka, K.VON, Syakir, M., Kochzius, M., 2014. Socio-economy
617 of marine ornamental fishery and its impact on the population structure of the clown
618 anemone fish *Amphiprion ocellaris* and its host anemones in Spermonde Archipelago,
619 Indonesia. *Ocean & Coastal Management* 100, 41-50.
- 620
- 621 Merlijn, A.G., 1989. The role of intermediaries in small-scale fisheries: a case study of
622 Sarawak, Malaysia. *Development and Change* 20, 683–700.
- 623
- 624 Nascimento, D.M, Mourão, J.S, Alves, R.R.N., 2011. A substituição das técnicas
625 tradicionais de captura do caranguejo-uçá (*Ucides cordatus*) pela técnica “redinha” no
626 estuário do rio Mamanguape, Paraíba. *Sitientibus* 11, 113-119.
- 627
- 628 Nascimento, D.M., Mourão, J.S., Ferreira, E.M., Bezerra, D.M.M.S.Q., Rocha, P.D.,
629 Alves, R.R.N., 2012. Capture techniques’ of *caranguejo-uçá* crabs (*Ucides cordatus*) in
630 Paraíba state (Northeastern Brazil) and its socio-environmental implications. *An Acad*
631 *Bras Ciênc* 84, 605-608.
- 632
- 633 Nascimento, D.M., Alves, A.G.C., Alves, R.R.N., Barboza, R.R.D, Diele, K., Mourão,
634 J.S., 2016. An examination of the techniques used to capture mangrove crabs, *Ucides*
635 *cordatus*, in the Mamanguape River estuary, northeastern Brazil, with implications for
636 management. *Ocean & Coastal Management* 130, 50-57.
- 637
- 638 Nishida, A.K., Nordi, N., Alves, R.R.N., 2006. The lunar-tide cycle viewed by
639 crustacean and mollusc gatherers in the State of Paraíba, Northeast Brazil and their
640 influence in collection attitudes. *Journal of Ethnobiology and Ethnomedicine* 2, 1-12.

641

642 Nordi, N., Nishida, A.K., Alves, R.R.N., 2009. Effectiveness of Two Gathering
643 Techniques for *Ucides cordatus* in Northeast Brazil: Implications for the Sustainability
644 of Mangrove Ecosystems. *Hum. Ecol.* 37, 121-127.

645

646 Ochiwo, J., Torre-Castro, M., Muthama, C., Munyi, F., Nthuta, J.M, 2010. Socio-
647 economic features of sea cucumber fisheries in southern coast of Kenya. *Ocean &*
648 *Coastal Management* 53, 192-202.

649

650 Paludo, D., Klonowski, V.S., 1999. Barra de Mamanguape – PB: estudo do impacto do
651 uso de madeira de manguezal pela população extrativista e da possibilidade de
652 reflorestamento e manejo dos recursos madeireiros. São Paulo: MAB – UNESCO –
653 MMA, n. 16, 1999. 54 p. (Série Cadernos da Reserva da Biosfera da mata Atlântica).

654

655 Pasquotto, V.F., 2007. Comercialização, políticas públicas e reprodução social na pesca
656 artesanal. In: Costa, A. L. (eds.). *Nas redes da pesca artesanal. Segunda Edição.* Edições
657 IBAMA, Brasília, Brasil.

658

659 Pauly, D., Christensen, V., Guénette, S., Pitcher, T.J., Sumaila, U.R., Walters, C.J.,
660 2002. Towards sustainability in world fisheries. *Nature* 418, 689-695.

661

662 Platteau, J.P., Abraham, A., 1987. An inquiry into quasi-credit contracts: the role of
663 reciprocal credit and interlinked deals in small-scale fishing communities. *Journal of*
664 *Development Studies* 23, 461-490.

665

- 666 Platteau, J.P, Nugent, J., 1992. Share contracts and their rationale: lessons from marine
667 fishing. *Journal of Development Studies* 28, 386–422.
- 668
- 669 Posey, D., 1987. Introdução – Etnobiologia: teoria e prática, in: Ribeiro, B. (Eds), *Suma*
670 *Etnológica Brasileira*. Vozes, Petrópolis, pp. 15-25.
- 671
- 672 Rahman, M., Khatun, S., Hossain, M.B., Hassan, M.N., Nowsad, A.A.K.M., 2013.
673 Present Scenario of Landing and Distribution of Fish in Bangladesh. *Pakistan Journal of*
674 *Biological Sciences* 16, 1488-1495.
- 675
- 676 Reis, M.R.R., 2007. Na Friadagem do Mangal: organizar e tirar caranguejos nos fins de
677 semana em Bragança (Vila do Acarajó). Dissertação de Mestrado. Universidade Federal
678 do Pará. 170p.
- 679
- 680 Russel, D.N., 1987. Intermediaries and moneylending: relations of exchange in a
681 highland Philippine economy. *Journal of Anthropological Research* 43, 139-61.
- 682
- 683 Saint-Paul, U., 2006. Interrelations among Mangroves, the Local Economy and Social
684 Sustainability: a Review from a Case Study in North Brazil. In.: *Environment and*
685 *Livelihoods in Tropical Coastal Zones*, eds Hoanh, C.T.; Tuong, T.P.; Gowing, J.W.;
686 Hardy, B., p. 154-162.
- 687
- 688 Santos, M.C.F., 2002. Drinking and osmoregulation in the mangrove crab *Ucides*
689 *cordatus* following exposure to benzene. *Comparative Biochemistry and Physiology -*
690 *Part A* 133, 29-42.

691

692 Sociedade Internacional para Ecossistemas de Manguezal – ISME, 2005. Estudo das
693 áreas de manguezais do Nordeste do Brasil. 56 p.

694

695 Sttebins, R.A., 1987. Fitting in: the researcher as leaner and participant. *Qual Quant* 21,
696 103-108.

697

698 Toledo, V.M., 1991. *El Juego de la Supervivencia: Un Manual para la Investigación*
699 *Etnoecológica en Latino-America*. Berkeley: California.

700

701 Vieira, R.H.S.F., Lima, E.A., Sousa, D.B.R., Reis, E.F., Costa, R.G., Rodrigues, D.P.,
702 2004. *Vibrio spp.* and *Salmonellaspp.*, presence and susceptibility in crab *Ucides*
703 *cordatus*. *Revista do Instituto de Medicina Tropical de São Paulo* 46, 179-182.

704

705 Wilson, J.A., 1980. Adaptation to uncertainty and small numbers exchange: the New
706 England fresh fish market. *The Bell Journal of Economics* 11, 491-504.

707

708 Wolff, M., Koch, V., Isaac, V., 2000. A trophic flow model of the Caeté mangrove
709 estuary (North Brazil) with considerations for the sustainable use of its resources.
710 *Estuarine, Coastal and Shelf Science* 50, 789-803.

711

712 Xavier, J.H.A., Cordeiro, C.A.M.M., Tenório, G.D., Diniz, A.F., Júnior, E.P.N.P., Rosa,
713 R.S., Rosa, I.L., 2012. Fish assemblage of the Mamanguape Environmental Protection
714 Area, NE Brazil: abundance, composition and microhabitat availability along the
715 mangrove-reef gradient. *Neotrop Ichthyol* 10, 109-122.