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Bio-ecological parameters to understand biodiversity of crabs in the protected area of the Ehotile Island National Park (Cote d'Ivoire) and its adjacent unprotected fishing areas

Coulibaly Lefoungognon, Bamba Mamadou, Nzi Konan Gervais*, Goore Bi Gouli

Hydrobiology Laboratory, Department of Biosciences, Felix Houphouet Boigny University, Abidjan, Cote d'Ivoire

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Abstract

This study was conducted to study the diversity of crabs and to identify the environmental parameters responsible for their spatial distribution in the Ehotile Island National Park and its adjacent areas. Crabs sampling was conducted monthly from January 2018 to March 2019. The fishing gears and technics used to catch crabs were balance crab fishing, traditional crab traps, fixednet, lobster pots, traps for water crabs and manual catch for land crabs. A total of 25 species of crabs belonging into 14 genuses and 7 families were identified. In the Ehotile National Park, 18 species belong to 5 families and 9 genuses were recorded. The most diversified family is Sesarmidae (39%) with seven species. Djakou and Thanon classification revealed that *C. armatum, S. huzardi, S. elegans, P. gracilis*, *G. pelii*, *H. africanus* and *P. africanus* are very frequent. In unprotected area, 3 families, 5 genuses and 7 species were noted. The most diversified family was Ocypodidae (57%) and the most abundant species was *Uca tangeri* (29.54%). Spearman correlation coupled to Canonical analysis showed that pH, dissolved oxygen, conductivity, water temperature, transparency, salinity, redox potential, depth, sand-gravel, sand-clay, sand-mud, leaf-deadwood and sand influence strongly abundance of crab species.

***Corresponding Author:** NZI Konan Gervais ✉ nzi.gervais@ufhb.edu.ci

Introduction

Macro-invertebrates in aquatic environments are natural resources of primary importance N'zi (2007). They are composed of species of high economic value (Bougard 1988) and represent a source of food for populations. Among these macro-invertebrates we have crabs that play an essential biological role in ecosystems. Indeed, crabs ensure the oxygenation of sediments by digging their burrows, and therefore the relative importance of anaerobic and aerobic mineralization processes of sedimentary organic matter (Dye et Lasiak 1987). Some crab species are used as indicators or biomarkers in the assessment of the quality of aquatic environments by toxic metals (Brian 2005; Stentiford et Feist 2005; Moreira *et al.*, 2006).

In Côte d' Ivoire, studies carried out on crabs only concerned the biological and ecological aspects. These are the works of Charles-Dominique et Hem (1981); Lhomme (1994); Guiral *et al.* (1999); Sankare *et al.* (2014); D'almeida *et al.* (2014).

Moreover, under the impetus of the development of cash crops and the timber industry, the disappearance of forest cover has increased with one of the highest rates in the world estimated at 6.5% per year (Schmidt 1990). This not only poses a threat to the preservation of natural habitats, refuge and spawning grounds, but also to some extent severely limits the spatial distribution of the various aquatic species [Hugueny *et al.*, 1996; Gourène *et al.*, 1999; Kamdem Toham and Teugels 1997; 1998 and 1999]. Also the intensification of human activities on the Island of the Ehotile Island National Parkhas led to a significant degradation of natural formations and only species that can survive in secondary environments are still present (Hilaire 2010). Increasing urbanization and the planting of populations living around the park pose a threat to the habitats of species living on the park's periphery.

In response to this situation, research work has been undertaken, for example in ornithology (Hilaire 2010) and botany (Malan *et al.*, 2007) in the Parc and its periphery areas. This work made it possible to show of the biological importance of Ehotile Island National Park as "exceptional" (Malan *et al.*, 2007).

Despite the extensive work carried out in the Ehotile Island National Park and the remarkable presence of crabs in this area, no study has been done on the diversity of crabs in this park and the influence of environmental variables on them. This work has been done to address this deficiency. Its general objective is to contribute to a better knowledge of the diversity of crabs in Ehotile Island National Park and its adjacent areas and to determine the parameters that influence their distribution with a view to their safeguarding.

Materials and methods

Study area

The present study was carried out in the Ehotile Islands National Park and its adjacent areas (Fig. 1). The park with an area of 722ha, is located in the South East of Côte d'Ivoire in Adiaké department between the parallels 3°16'43" and 3°18'52" West longitude and 5°9'45" and 5°11'12" North latitude. It is composed to six islands [Assokomonobaha or Assoko (327.5ha), Balouhaté (75ha), Méha (45ha), Nyamouin (47.5ha), Elouamin (22.5ha) and Bosson Assoun (32.5ha)]. These islands are surrounded by Aby Lagoon, which covers the catchment area of 305 km² with an average depth of 4.6 m. This lagoon is characterized by low salinity of water in its eastern region. It receives the Bia River in its northern part and is connected to the Atlantic Ocean by the Assinie Canal in its southern part (Chantraine 1980). Adjacent areas of the park are the coastal areas represented by Assinie located between 3°16'78" W and 5°7'84" N on Onehand and Melekoukro River located between the longitude 3°20'18" W and 5°13'58" N on otherhand.

Environmental parameters data

Measurements of the parameters were carried out monthly in situ, between 7 a.m. and 9 a.m. from January 2018 to March 2019 for the characterization of the environments (Table 1). For each station visited, the temperature (°C), conductivity (µS/cm), redox potential (mV), hydrogen potential, salinity (mg/l) were measured using a multi-parameter HQ 30d brand. As for dissolved oxygen (mg/l), it was measured using a multi-parameter SANXIN brand.

The depth (cm) was measured using a bamboo. A 30cm diameter Secchi disc painted in white-black was used to assess the transparency of the water. The canopy closure rate and substrates consisting of sand, sand-gravel, sand-mud, sand-clay and leaf-wood dead mixture were used to characterize the habitat (Table 2).

Sampled sites and crabs fishing gears

Fifteen stations were selected based on habitat diversity, their accessibility and the presence or absence of crabs in each area. Thirteen stations (Assoko 1, Assoko 2, Balouaté 1, Balouaté 2, Elouamin 1, Elouamin 2, Méha 1, Méha 2, Niamouin 1, Niamouin 2, Aby 1, Aby 2, Aby 3) were sampled in the park and two in the adjacent areas (Assinie and Melekoukro River) (Fig. 1). Crabs were sampled monthly from January 2018 to March 2019 using crab balances, mesh net, fixed net, lobster pots and manual catch.

In each sampling site, gears were set between 5:00 pm and 7:00 am for night catches, and between 7:00 am and 5:00 pm for day catches. Manual catches were done by digging crab burrows. Crabs captured were conserved into formaldehyde 10% and transported to the laboratory for identification. All cabs were identified using identification and determination keys of Manning *et al.* (1981) and Monod (1956).

Data analysis

In the present study, numerical percentage, percentage of occurrence and Redundancy Analysis (RDA), using CANOCO (Canonical Community Ordination, version 4.5) (ter Braak & Šmilauer, 2003) were used for data analysis.

Numerical percentage (%N)

It is the number of individuals in a species (n) in relation to the total number of individuals surveyed (Nt) multiplied by one hundred.

%N = (n/Nt) x100.

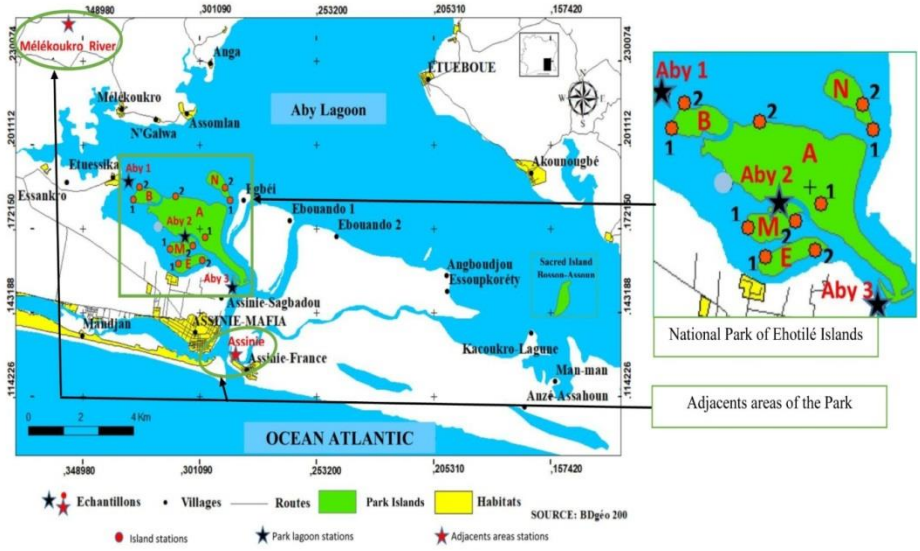

Fig. 1. Sampling sites of the Ehotilé Island National Park [(A=Assoko, B=Balouaté, E=Elouamin, M=Méha, N=Niamouin) (•), (Aby 1, Aby 2, Aby 3)] (★) and its adjacents areas (Assinie and Melekoukro river) (★)

Percentage of occurrence (%O)

It is the number of stations (Pi) where a species (i) is sampled in relation to the total number of stations surveyed (Pt) multiplied by one hundred. %O = (Pi/Pt) x 100. The classification of Djakou and Thanon (1988) was used and is as follows: Very frequent species (80 <%O≤100), frequent species (60 <%O ≤79), fairly frequent species (40 <%O≤59%), accessory species (20 <%O≤39), accidental species (%O ≤ 20). Shannon-Weaver (1963) diversity index (H) was used to characterize crabs from different study environments. According to Ludwig and Renolds (1988), the Shannon diversity index (H) is zero if and only if the sample is composed of a single species and maximum (on the order of 5) if all the species in the community have a perfect distribution of abundance.

This means that this index is low when there is an imbalance in the distribution of individuals per species.

$H = - \sum_{i=1}^{i=s} pi \times \log 2pi$

with: S = number of species, pi = proportion of the ith species (i varying from 1 to S). The equitability index (E) of Hill (1973) was used to measure the evenness of species distribution. Hill's equitability (E) varies between 0 and 1, and is equal to 0 when a single species dominates the stand and 1 when all species have the same relative abundance. E = H'/log2 S; With S = specific wealth and H'= Shannon diversity index. The Spearman correlation test was used to analyze the relationship between species abundance and environmental variables.

The Canoco for Windows version 4.1 program was used for Redundancy Analysis (RDA) to investigate possible correlations between environmental variables and crabs community assemblages. Therefore, two matrices covering the 15 sampling stations and 14 environmental variables were constructed: (1) numerical abundance of all species collected and (2) environmental variables. The influence of environmental variables on species abundance in Ehotile National Park and its adjacent areas was demonstrated by the Spearman correlation analysis and by a redundancy analysis (RDA) based on two matrices: "absolute abundance of species/ stations" and "environmental variables/stations".

Table 1. Variations of the physico-chemical parameters measured at the various sampling stations in Ehotilé Islands National Park and its adjacent areas (Côte d'Ivoire) between January 2018 and March 2019. Oxyg= dissolved oxygen; pH= Hydrogen potential; P.red= Redox potential; Temp= Water temperature; Cond= Conductivity; Sal= Salinity; Prof= Depth; Trans= Transparency; Max= maximum; Min= minimum and Mean= mean

	Ehotile Islands National Park			Adjacents areas		
	Max	Min	Moy	Max	Min	Moy
Temp	32.4	27.7	29.71±0.31	27.9	24.6	25.6±1.55
pH	6.99	5.41	636±0.28	6.57	4.95	5.82±0.67
Cond	454.25	84.33	23301±31.01	503.4	57.56	310.08±202.06
Sal	2.08	0.04	0.34±0.20	0	0	0
P.red	293.1	64.3	178.38±178.38	132.6	69	108.28±28.07
Prof	213	377	296.66±29.36	52.55	30.2	40.78±9.46
Trans	145	64	101.33±32.95	45.2	27.3	36.5±9.15
Oxyg	7.54	4.36	5.69±0.17	6.54	3.57	5.01±1.22

Table 2. Average values in percent of the rate of substrate components, and of the canopy closure rate of the different stations of the Ehotilé Islands National Park and its adjacent areas from January 2018 to March 2019. CAN = canopy; MSB = sand-mud mixture; FBm = Deadwood leaves; MSA = sand-clay mixture; MSG = sand-gravel mixture, SA=sand.

Stations	CAN (%)	MSB (%)	FBm (%)	SA (%)	MSA (%)	MSG (%)
Assoko 1	10	80	15	5	15	0
Assoko 2	70	10	30	10	5	40
Niamouin 1	20	10	25	20	5	15
Niamouin2	85	0	60	55	5	75
Balouaté 1	70	90	20	3	10	0
Balouaté 2	65	15	30	15	5	50
Méha 1	30	40	10	5	5	0
Méha 2	70	10	25	40	5	37
Elouamin 1	5	40	30	5	7	2
Elouamin 2	90	0	45	35	2	45
Asssinie	0	0	0	95	0	10
Melekoukro River	20	5	10	70	0	35
Aby lagoon	0	15	5	80	0	20

Results

Crabs composition in Ehotile Islands National Park

A total of 5718 crabs were sampled in Ehotile Islands National Park and its adjacent areas. Specimens were divided into 18 species, 5 families and 9 genuses (Table 3). Among species sampled, four species, *Cardisoma* sp, *Sesarma* sp, *Sarmatim* sp and *Goniopsis* sp were unidentified and are observed the first time in Cote d'Ivoire.

Distribution of crabs specimens according to families is shown by Fig. 2. The most diversified family is Sesarmidae (39% of total specimens) with seven species constituted by *Sesarma huzardi*, *S. alberti, S. buettikoferi*, *S. elegans, Sesarma* sp, *Sarmatium curvatum* and *Sarmatium* sp).

It is followed by Grapsidae familly (22%) with four species (*Pachygrapsus gracilis*, *P. transversus*, *Goniopsis pelii, Goniopsis* sp); Xanthidae familly (17%) with three species (*Heteropanope africanus*, *Panopeus africanus* and *Pilumnopeus africanus*); Gecarcinidae familly (11%) with two species (*Cardisoma armatum* et *C.* sp) and Portunidae familly (11%) with two species (*Callinectes amnicola* and *C. pallidus*).

Taking into account the distribution, families of Sesarmidae, Xanthidae and Gecarcinidae were caught on the islands in Ehotile Islands National Park of as well as Portunidae exclusively caught in the lagoon located in the park.

The greatest specific richness was recorded in Ehotile Islands National Park with 18 species, including 16 on the islands and two exclusively into Aby lagoon located in the park.

Spatio-temporal variations and crabs abundance

Data on the distribution of crabs caught in Ehotile Islands National Park show that there is a variation in specific richness according to the catch sites. The most abundant species richness was observed at the station Balouate with 14 species. It is followed by Elouamin station (12 species), Meha (10 species), Assoko (9 species) and Niamouin (8). The poor species richness was obtained in Aby station with 2 species.

Table 3. Crab species composition in Ehotile Islands National Park between January 2018 and March 2019. (+) = Presence.

Families	Genuses	Species	Balouaté	Niamouin	Elouamin	Assoko	Méha	Aby
Gecarcinidae	*Cardisoma*	*Cardisoma armatum*	+	+	+	+	+	
		Cardisoma sp	+	+	+		+	
Portunidae	*Callinectes*	*Callinectes amnicola*						+
		Callinectes pallidus						+
Sesarmidae	*Sesarma*	*Sesarma huzardi*	+	+	+	+	+	
		Sesarma alberti			+			
		Sesarma sp	+		+			
		Sesarma elegans	+	+	+	+	+	
		Sesarma buettikoferi	+		+	+		
	Sarmatium	*Sarmatium curvatum*	+			+	+	
		Sarmatim sp	+				+	
Grapsidae	*Pachygrapsus*	*Pachygrapsus gracilis*	+	+	+	+	+	
		Pachygrapsus transversus	+					
	Goniopsis	*Goniopsis pelii*	+	+	+	+	+	
		Goniopsis sp	+					
Xanthidae	*Heteropanope*	*Heteropanope africanus*	+	+	+	+	+	
	Panopeus	*Panopeus africanus*	+	+	+	+	+	
	Pilumnopeus	*Pilumnopeus africanus*			+			
			14	8	12	9	10	2

According specific richness, the most abundant species is *Callinectes amnicola* with 2316 individuals or 40.36%. They are followed by *Sesarma huzardi* (1988 individuals or 34.64%), *Cardisoma armatum* (930 individuals or 16.20%), *Callinectes pallidus* (152 individuals or 2.65%), *Sesarma elegans* (81 individuals or 3.88%), *Pachygrapsus gracilis* (75 individuals or 1.31%), *Sesarma buettikoferi* (44 individuals or 0.77%), *Goniopsis pelii* (43 individuals or 0.75%), *Cardisoma sp* (27 individuals or 0.47%), *Heteropanope africanus* (26 individuals or 0.45%), *Sarmatium curvatum* (21 individuals or 0.37%), *Panopeus africanus* (20 individuals or 0.35%), *Sarmatim* sp (6 individuals or 0.10%), *Sesarma* sp (5 individuals or 0.09%). Other species constitued by *Sesarma alberti*, *Pachygrapsus transversus*, *Goniopsis* sp, *Pilumnopeus africanus*) with one (1) individual (0.02%) respectivily are less abundant (Fig. 3). Depending on the season, the greatest abundance of crabs 3128 (54.51%) has been observed in the rainy season. In the dry season, only 2610 (45.49%) have been noted in the dry season.

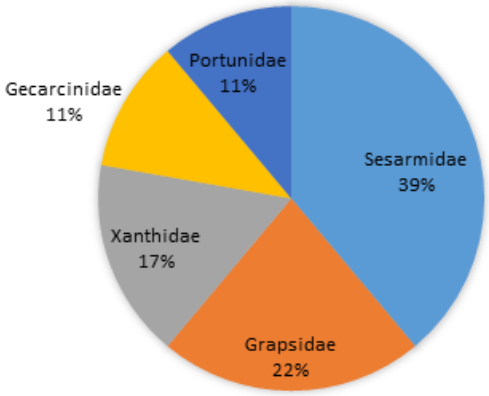

Fig. 2. Percentage of crab families sampled in Ehotile Islands National Park between January 2018 to March 2019.

Occurrence of crabs community species

Throughout Ehotile Islands National Park, Djakou and Thanon (1988) classification of the different crabs species according to their percentage of occurrence revealed that the species *Cardisoma armatum* (83.33%), *Sesarma huzardi* (83.33%), *Sesarma elegans* (83.33%), *Pachygrapsus gracilis* (83.33%), *Goniopsis pelii* (83.33%), *Heteropanope africanus* (83.33%) and *Panopeus africanus* (83.33%) are very frequent. *Cardisoma* sp (66.66%) is a frequent species. *Sesarma buettikoferi* (50%) and *Sarmatium curvatum* (50%) are fairly frequent species. *Sesarma* sp (33.33%) and *Sarmatium* sp (33.33%) are accessory species. *Callinectes amnicola* (16.66%), *Callinectes pallidus* (16.66%), *Sesarma alberti* (16.66%), *Pachygrapsus transversus* (16.66%), *Goniopsis* sp (16.66%) and *Pilumnopeus africanus* (16.66%) are accidental species.

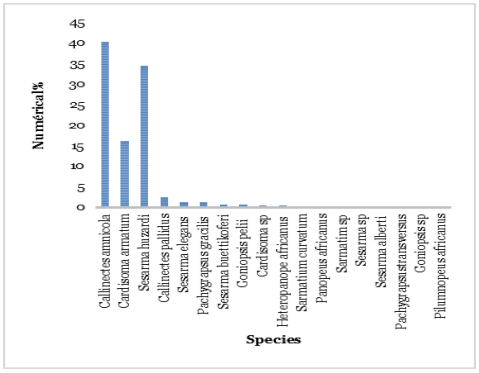

Fig. 3. Numerical percentage of crab species caught in Ehotile National Park between January 2018 and March 2019.

Calculation of the indices based on the numbers of crab species sampled in the Ehotile Islands National Park indicates that the values of the Shannon Diversity Index (H) and the Equitability Index (E) are H=1.43 and E=0.49, respectively. Seasonal variations show that the highest values of the Shannon (H) and Equitability (E) diversity indices were observed during the dry season (H=1.51 and E=0.56). Conversely, the lowest values were obtained in the rainy season with H=1.31 and E=0.47.

Crabs composition in adjacent areas

A total of 325 crabs were sampled in Ehotile Island National Park adjacent areas. Specimens were divided into 3 families, 5 genuses and 7 species (Table 4). Among species sampled, *Uca* sp were unidentified and *Planes minutus* was identified. Both species are observed for the first time in Cote d'Ivoire. Distribution of crabs specimens according to families is shown by Fig. 4. The most diversified family is Ocypodidae familly (57%) with four species (*Uca tangeri*, *U.* sp, *Ocypode africana* and *O. cursor*). It is followed by Grapsidae familly (29%) with two species (*Grapsus grapsus* and *Planes minutus*) and Potamidae familly (14%) with one species (*Liberonautes latidactylus*). The families of Ocypodidae and Grapsidae were caught in Assinie station. Potamidae familly were collected in the Melekoukro River stations.

Table 4. Crab species inventoried in adjacent areas between January 2018 and March 2019. (+) = Presence.

Families	Genuses	Species	Assinie	Melekoukro River
Ocypodidae	Uca	*Uca tangeri*	+	
		Uca sp	+	
	Ocypoda	*Ocypode africana*	+	
		Ocypode cursor	+	
Grapsidae	Grapsus	*Grapsus grapsus*	+	
	Planes	*Planes minutus*	+	
Potamidae	Liberonaute	*Liberonautes latidactylus*		+
			6	1

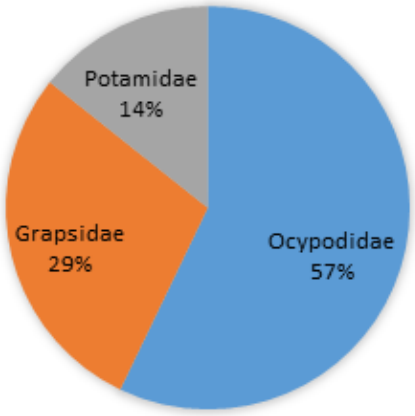

Fig. 4. Percentage of crab families sampled in adjacent areas between January 2018 to March 2019.

Spatio-temporal variations and crabs abundance

Distribution of crabs caught in adjacent areas showed that there is a variation in specific richness according to the catch sites. The most abundant species richness was observed at the station Assinie with 6 species. It is followed by Melekoukro River station with 1 species.

According specific richness, the most abundant species is *Uca tangeri* with 96 individuals (29.54%). It is followed by *Ocypode africana* which 84 individuals (25.84%), *Ocypode cursor* and *Liberonautes latidactylus* 69 individuals (21.23%) respectivily, *Uca* sp 5 individuals (1.54%). *Grapsus grapsus* and *Planes minutus* with 1 individual or 0.31% respectivily (Fig. 5). Depending on seasons, hight the most abundance specimens of crabs, 200 (61.53%) was recorded in rainy season. During dry season 125 (38.46%) specimens of crabs were noted.

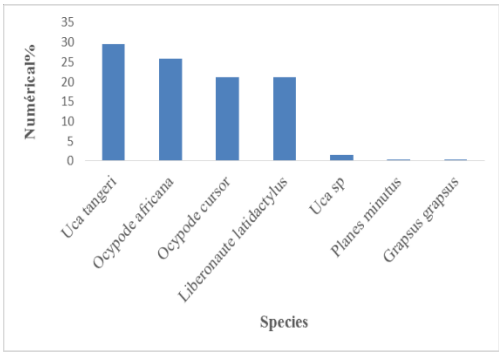

Fig. 5. Numerical percentage of crab species caught in all adjacent areas.

Occurrence of crabs community species

In all adjacent areas, the classification of the different crab species according to their percentage of occurrence has shown that *Uca tangeri, Uca* sp, *Ocypode africana, Ocypode cursor*, *Grapsus grapsus*, *Planes minutus* and *Liberonautes latidactylus* are quite frequent with occurrences of 50%.

Calculation of the indices based on the numbers of crab species sampled in adjacent areas indicates that the values of the Shannon Diversity Index (H) and the Equitability Index (E) are H= 1.47 and E= 0.75 respectively. Taking into account the seasons, the values of the Shannon diversity index (H) are lower (H=1.41) while Equitability is higher (E=0.88) during the rainy season. Conversely, the Shannon diversity index (H) is higher (H=0.52) while Equitability is lower (E=0.78) in the dry season.

Crabs communities and environmental factors

Spearman correlation analysis (Table 5) and a redundancy analysis (RDA) based on absolute abundance of species/stations' and "environmental variables/stations' matrices (Fig. 6) showed the influence of environmental variables on species abundance in Ehotile Islands National Park and its adjacent areas. Spearman correlation analysis carried out on the sampled species showed that pH, dissolved oxygen content, conductivity, water temperature, transparency, salinity, redox potential, depth, percentage of sand-gravel, sand-clay, sand-mud, leaf-deadwood mixture and sand strongly influence the abundance of crab species ($p < 0.05$). The abundance of the species *C. amnicola*, *C. pallidus* and *L. latidactylus* is negatively correlated to the sand-clay mixture and positively to pH, dissolved oxygen level, conductivity, water temperature, transparency, salinity, redox potential and depth. The abundance of *C. armatum*, *C. sp* and *S. buettikoferi* is positively correlated with leaf and dead wood mixtures. The species *S. huzardi*, *S. elegans* and *S. curvatum* are negatively correlated to sand and sand-gravel mixture but positively correlated to sand-mud and sand-clay mixture.

The abundance of *H. africanus* and *Sarmatim* sp is negatively correlated with sand and sand-gravel mixture but positively correlated with sand-mud mixture. *G. pelii* and *P. africanus* are negatively correlated to sand and positively correlated to the sand-mud and sand-clay mixture. For the species *U. tangeri*, *U.* sp, *O. africana*, *O. cursor*, their abundance is negatively correlated with the mixture of sand-mud, dead wood leaves and sand-clay but positively correlated with sand.

Throughout the study area, the ordination of correlations by canonical analysis in RDA indicates that factor axis 1 (eigenvalue $\lambda 1 = 0.524$) and axis 2 (eigenvalue $\lambda 2 = 0.137$) express 76% of the cumulative variance for species and environmental variables data. The RDA ordination along factor axis 1 identifies two groups of crabs associated with environmental variables. Group I consists of the following species *Sesarma huzardi, Sesarma elegans,*

Sesarma alberti, *Sesarma* sp, *Pilunopeus africanus, Pachygrapsus gracilis, P. transversus, Goniopsis pelii, G.* sp, *Heteropanope africanus, Panopeus africanus, Sarmatium curvatum* and *Sarmatium* sp. This group of species positively correlated to axis 1 is associated with stations Ass 1, Bal 1, Méa1, Nia 1 and Elo 1. These stations are characterized by a high percentage of sand-mud and sand-clay mixing. Group II contains the species *Cardisoma armatum, Cardisoma* sp and *S. buettikoferi*. These species negatively correlated to axis 1 are associated with the stations Ass 2, Bal 2, Méa 2, Nia 2 and Elo 2 are characterized by a high percentage of sand-gravel mixture, dead wood leaves and a closed canopy.

The ordination of correlations along factor axis 2 isolates one group of species. This group is constitued by *C. amnicola*, *C. pallidus* and *L. latidactylus*. It is positively correlated to axis 2 and associated with Aby and Melekoukro River stations. These stations are characterized by pH, dissolved oxygen, conductivity, water temperature, transparency, salinity, redox potential and water depth. In this same group there are *Uca tangeri*, *Uca* sp, *Ocypode africana*, *Ocypode cursor, Grapsus grapsus* and *Planes minutus*. Those species were caught in Assinie station which is influenced by the significant presence of fine sand.

Table 5. Spearman correlation coefficients (r) between Crabs species abundance and environmental variables in the Ehotilé Islands National Park and its adjacent areas (Côte d'Ivoire) from January 2018 to March 2019. T = water temperature, pH = hydrogen potential, Ox = dissolved oxygen content, Cond = conductivity, Trans = transparency, Sal = salinity, P.red = redox potential, Prof = depth, MSG = sand-gravel mixture, MSA = sand-clay mixture, MSB = sand-mud mixture, FBm = dead wood leaves, SA = sand. * significant correlations values (*).

	Environmental variables													
Species	T	pH	Cond	Sal	P.red	Prof	Trans	Ox	CAN	MSB	FBm	SA	MSA	MSG
C. armatum	0	0	0	0	0	0	0	0	0.18	-0.17	0.42*	0.05	0.11	0.25
C. sp	0	0	0	0	0	0	0	0	0.09	-0.15	0.45*	0.15	0.01	0.22
C. amnicola	0.73*	0.73*	0.64*	0.99*	0.73*	0.61*	0.73*	0.7*	-0.35	0	-0.4	0.33	-0.38*	0.37
C. pallidus	0.73*	0.73*	0.64*	0.99*	0.73*	0.61*	0.73*	0.7*	-0.35	0	-0.4	0.33	-0.38*	0.37
S. huzardi	0	0	0	0	0	0	0	0	0.15	0.62*	0.12	-0.7*	0.49*	-0.5*
S.alberti	0	0	0	0	0	0	0	0	-0.12	0.2	0.25	-0.2	0.28	-0.1
S. sp	0	0	0	0	0	0	0	0	0.14	0.37	-0	-0.35	0.22	-0.3
S. elegans	0	0	0	0	0	0	0	0	0.26	0.5*	0.04	-0.62*	0.42*	-0.4*
S. buettikoferi	0	0	0	0	0	0	0	0	0.14	-0.2	0.44*	0.17	0	0.18
S. curvatum	0	0	0	0	0	0	0	0	0.05	0.64*	-0.1	-0.6*	0.39*	-0.6*
Sarmatim sp	0	0	0	0	0	0	0	0	0.3	0.47*	-0.3	-0.52*	0.12	-0.4*
P. gracilis	0	0	0	0	0	0	0	0	0.36	0.36	0.08	-0.51*	0.27	-0.3
P. transversus	0	0	0	0	0	0	0	0	0.28	0.33	-0.2	-0.33	0.18	-0.2
G. pelii	0	0	0	0	0	0	0	0	0.23	0.43*	0.19	-0.51*	0.48*	-0.4
G. sp	0	0	0	0	0	0	0	0	0.28	0.33	-0.2	-0.33	0.18	-0.2
P. minutus	0	0	0	0	0	0	0	0	-0.24	-0.29	-0.3	0.25	-0.3	-0.2
G. grapsus	0	0	0	0	0	0	0	0	-0.24	-0.29	-0.3	0.25	-0.3	-0.2
H. africanus	0	0	0	0	0	0	0	0	0.05	0.71*	-0.1	-0.74*	0.38	-0.6*
P. africanus	0	0	0	0	0	0	0	0	0.17	0.43*	0.15	-0.51*	0.46*	-0.3
P. africanus	0	0	0	0	0	0	0	0	-0.12	0.2	0.25	-0.2	0.28	-0.1
U. tangeri	0	0	0	0	0	0	0	0	-0.35	-0.42*	-0.5*	0.42*	-0.38*	-0.4
U. sp	0	0	0	0	0	0	0	0	-0.35	-0.42*	-0.5*	0.42*	-0.38*	-0.4
O. africana	0	0	0	0	0	0	0	0	-0.35	-0.42*	-0.5*	0.42*	-0.38*	-0.4
O. cursor	0	0	0	0	0	0	0	0	-0.35	-0.42*	-0.5*	0.42*	-0.38*	-0.4
L. latidactylus	0.61*	0.61*	0.7*	-0.1	0.61*	0.73*	0.61*	0.64*	0	-0.2	-0.2	0.33	-0.38*	0.35

Oxyg= dissolved oxygen; pH= Hydrogen potential; P.red = Redox potential; Temp = Water temperature; Cond = Conductivity; Sal=Salinity; Depth=Depth; Trans=Transparency. CAN = canopy; MSB = sand-mud mixture; Deadwood leaves; MSA = sand-clay mixture; MSG = sand-gravel mixture, SA=sand. Ass =Assoko, Bal=Balouaté, Elo=Elouamin, Nia=Niamouin, Mél.Riv =Melekoukro River : Car.arm=*Cardisoma armatum,* Car.sp=*Cardisoma* sp, S.alb=*Sesarma alberti*, S.huz=*Sesarma huzardi, S.eleg=Sesarma elegans,*

S.bue=*Sesarma buettikoferi,* S.sp=*Sesarma* sp, P.gra=*Pachygrapsus gracilis*, P.trans=*Pachygrapsus transversus*, G.pel=*Goniopsis pelii*, G.sp=*Goniopsis* sp, H.afr=*Heteropanope africanus*, Pa.afr=*Panopeus africanus*, Sa.cu=*Sarmatium curvatum*, Sa.sp= *Sarmatium* sp, Cal.a=*Callinectes amnicola*, Cal.p=*Callinectes pallidus*, P.afr=*Pilumnopeus africanus*, U.tan=*Uca tangeri,* U.sp=*Uca* sp, O.afr=*Ocypode africana,* O.cur=*Ocypode cursor*, G.gra=*Grapsus grapsus*, P.min=*Planes minutus*, L.lat=*Liberonautes latidactylus*

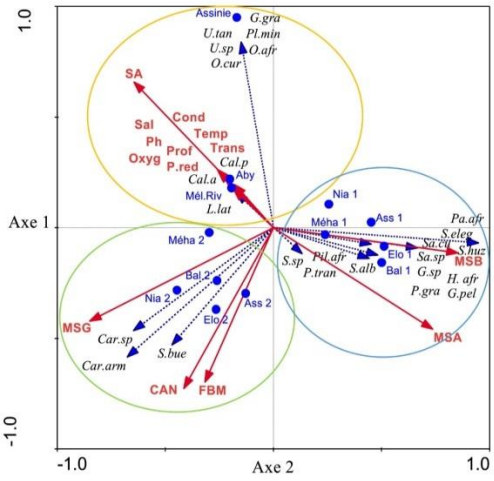

Fig. 6. Results of the Redundancy Analysis (RDA) showing the relationships between environmental variables, sampling stations and crab taxa in Ehotile Islands National Park and its adjacent areas (Cote d'Ivoire) from January 2018 to March 2019.

Discussion

The inventory of 6043 crab specimens in the Ehotilé Islands National Park and its adjacent areashas identified 25 species distributed among seven families and 14 genuses. Among these species, five are undeterminated. This taxonomic diversity at family rank is identical to that obtained in previous work in Guinea Cumberlidge (2006), Benin and Cote d'Ivoire (Guiral *et al.*, 1999) but different from that obtained in Senegal, and Gambia (Guiral *et al.*, 1999) where the family Gecarcinidae has not been reported.

In terms of specific richness, 20 valid species are been inventoried in this study. Our results are higher than those obtained by Cumberlidge (2006) in Guinea (15 species) and Guiral *et al.* (1999) in Senegal (8 species), Gambia (10 species), Benin (11 species) and Cote d'Ivoire (15 species). The significantly high value of specific wealth in our study could be related to habitat diversity in the sampling method and period (Kouamélan *et al.*, 2003).

The presence of genuses such as Uca and Sesarma in our samples as well as in previous work corroborates Cumberlidge (2006) observations. Indeed, the latter states that these two genuses tend to be present in all mangrove habitats in the world and each time constitute the basis of the mangrove Decapoda fauna. Among species sampled, five (*Cardisoma* sp, *Sesarma* sp, *Sarmatim* sp, *Goniopsis* sp, *Uca* sp) were unidentified and one (*Planes minutus*) was identified for the first time in Cote d'Ivoire. the presence of these new species in our catches could be related to the fishing method used, the habitat types sampled and the sampling periods (Kouamélan *et al.*, 2003).

The very high specific richness of Ehotile Islands National Park in relation to the adjacent areas surveyed is due, on the one hand, to the most diversity of habitats constituted by significant presence of mangroves, forest and coco trues. On the other hand, this protected areas constituted is a refuge and breeding area for these species. As contrario, The low number of species observed in adjacent areas could be explained by the fishing pressure exerted on these species in this unprotected area.

Similarly, for many crabs, mangroves represent a good biotope for the construction of burrows (Odum and Heald 1975; Longhurst et Pauly 1987; Diouf 1996; Guiral *et al.*, 1999). In the Ehotile Islands National Park, the species *Cardisoma armatum* (83.33%), *Sesarma huzardi* (83.33%), *Sesarma elegans* (83.33%), *Pachygrapsus gracilis* (83.33%), *Goniopsis pelii* (83.33%), *Heteropanope africanus* (83.33%) and *Panopeus africanus* (83.33%) are very frequent species. This would be linked to favourable living conditions on the onehand and their ability to adapt to seasonal variations and environmental conditions on the other. In the Ehotile Islands National Park,

the value of the Shannon Diversity Index (H=1.43) shows an imbalance in the distribution of individuals per species while the Equitability Index (E=0.49) shows that almost half of the species have the same abundance and a regular distribution.

The high value of the Shannon's diversity index (H) and the Equitability index (E) in the dry season in the Ehotile Islands National Park shows an increase in the number of species having the same abundance with a more regular and balanced distribution per species. This would be explained by favourable living conditions for these species during this period.

In adjacent areas, the calculation of the Shannon (H=1.47) and Equitability (E=0.75) indices of diversity based on the numbers of crabs species sampled indicates an imbalance in the distribution of individuals per species and shows that more than half of the species have the same abundance with a regular distribution.

Taking into account the seasons, the value of the Shannon Diversity Index (H) is lower while the Equitability (E) is higher in the rainy season. This shows that almost all species have the same abundance with a more regular distribution but present a more pronounced imbalance in the distribution of individuals per species during this season.

Taking into account the distribution, the families of Sesarmidae, Xanthidae and Gecarcinidae were caught in the Ehotile Islands National Park as well as Portunidae exclusively caught in the lagoon environment of the park. The families of Ocypodidae and Potamidae were caught in the adjacent areas in Assinie and Melekoukro River station respectively. The Grapsidae were collected on the islands and at the Assinie station. This unequal distribution of crabs in the sampling sites shows that crabs have a preference for certain biotopes. Those harvested on the islands are very attached to the closed canopy and mangroves. Crabs species caught in the Aby lagoon located in the park have a preference for brackish water. Crabs harvested from the Melekoukro River are freshwater species. Crabs harvested at the Assinie station prefer open canopy environments with a substrate composed of fine sand. These crabs can therefore be described as beach crab. The particular presence of *Grapsus grapsus* and *Plane minutus* in this station could be explained by the permanent alternation between the Aby lagoon waters and the sea where salinity could be higher on the one hand and the nature of the substrate on the other hand. The study of seasonal variations shows that crabs are more abundant in the rainy season than in the dry season. This could be explained by the more favourable living conditions for aquatic organisms during this period. Indeed, the rainy season is marked by a better oxygenation of the water due to the agitation caused by the water current and by the arrival of large quantities of food caused by the flooding and/or the rainfall regime which favours the fall into the water of fruits, plant debris and terrestrial invertebrates (Castillo-Rivera 2013).

Analysis of the correlation between environmental variables, sampling stations and crab taxa has shown that the diversity of the crab species is influenced by physicochemical and hydro-edaphical parameters. It appears that the nature of the substrate, canopy and salinity play an important role in the distribution of crabs, resulting in three groups of crabs.

The first group includes the species Sesarma huzardi, *Sesarma elegans, Sesarma alberti, Sesarma* sp, *Pilunopeus africanus, Pachygrapsus gracilis*, *P. transversus, Goniopsis pelii, Goniopsis* sp, *Heteropanope africanus, Panopeus africanus, Sarmatium curvatum* and *Sarmatium* sp. These species are semi-terrestrial crabs and are characterized by a high percentage of sand-mud and sand-clay mixture.

The second group is composed by *Cardisoma armatum*, and *Cardisoma* sp. These species are land crabs. They are positively correlated with dead leaf-wood mixtures and characterized by a high percentage of sand-gravel, dead leaf-wood mixture and a closed canopy. The third group consists of crabs caught in the Melekoukro River located in the adjacent areas and the Aby lagoon located in the parc. They are referred to as freshwater crabs (*L. latidactylus*) and

brackish water (*C. amnicola* and *C. pallidus*) respectively. These species are positively correlated to pH, dissolved oxygen content, conductivity, water temperature, transparency, salinity, redox potential and depth but strongly influenced by salinity. In the same group we have crabs harvested at the Assinie station and are referred to as beach crabs (*Uca tangeri*, *Uca* sp, *Ocypode africana*, *Ocypode cursor*). They are influenced by the presence of fine sand on the beaches.

Conclusion

Across the Ehotile Islands National Park and its adjacent areas, 25 species of crab belonging into seven families and 14 genuses were sampled. These species are distributed between islands (16), sandy beaches (6), brackish waters (2) and fresh waters (1). The Ehotile Islands National Parkhas the highest number of species (18) compared to 7 species for adjacent areas. The good specific richness of the park reflects the interest there is in protecting it because it constitutes for these species a breeding area on the one hand and a refuge area in order to escape predators and fishing pressure on the other hand. Analysis of the correlation between environmental variables, sampling stations and crab taxa showed that substrate nature, canopy and salinity play an important role in crab distribution. Thus, despite the small size of our study area, ithas a fairly diverse crab fauna, similar to that of many West African countries.

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Conflicts of interest

The authors declare no conflicts of interest.

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