American Journal of Life Sciences
2026, Vol. 14, No. 6, pp. 154–166
https://doi.org/10.11648/j.ajls.20261406.12

Research Article

Influence of the Physicochemical Parameters of Interstitial Water on the Population Distribution of *Afruca tangeri* in the Mangrove Ecosystems of the Saloum Delta, Senegal

Combe Thiam[1, 2, *], Serigne Modou Sarr[1], Youssouph Diatta[2]

[1]Higher Institute for Agricultural and Rural Training (ISFAR), Alioune Diop University, Bambey, Senegal
[2]Marine Biology Laboratory, Fundamental Institute of Black Africa, Dakar, Senegal

Abstract

This study investigated the influence of environmental factors on the distribution of *Afruca tangeri* across three mangrove belts in the Saloum Delta National Park through annual population monitoring based on burrow counts, combined with the analysis of physicochemical parameters of interstitial water collected from the burrows. Sampling was conducted from August 2023 to July 2024 during low tide at the Bakadadji, Missirah, and Bettenty sites. The results showed that interstitial water temperature and pH were relatively homogeneous among mangrove belts and study sites, with average values of approximately 30 ℃ and pH ranging from 6 to 7. In contrast, electrical conductivity (EC, mS/cm), salinity (psu), and dissolved oxygen (DO, mg/L) exhibited marked spatial variations across mangrove belts and sites. Statistical analyses using the Kruskal–Wallis test indicated that most physicochemical parameters did not differ significantly ($p > 0.05$), except for salinity, which showed highly significant variation ($p < 0.05$). The mean population density of A. tangeri was estimated at 63.02 individuals/m^2 across the study area. Density varied significantly among mangrove belts, reaching the highest values under Rhizophora (100 ind/m^2), intermediate values under Avicennia (71.7 ind/m^2), and the lowest values in unvegetated areas (49.1 ind/m^2). At the site level, the highest densities were recorded at Bakadadji (68.67 ind/m^2) and Missirah (67.60 ind/m^2), compared with Bettenty, although these differences were not statistically significant ($p > 0.05$). Principal Component Analysis (PCA) biplot revealed that variations in A. tangeri density were closely associated with the physicochemical characteristics of the habitat, particularly salinity and dissolved oxygen. Salinity emerged as the main factor controlling the spatial distribution of A. tangeri with in the Saloum Delta National Park.

Keywords

Afruca Tangeri, Bioturbation, Burrow, Physicochemical Factors, Saloum Delta, Senegal

*Correspondence: Combe Thiam (thiamcombe03@gmail.com)

Received: 15 October 2026; **Accepted:** 3 November 2026; **Published:** 19 November 2026

Copyright: © The Author(s), 2026. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

1. Introduction

Mangroves are the dominant ecosystems that line the coasts of subtropical and tropical countries around the world. They function as nurseries for a wide variety of marine vertebrate and invertebrate species [1]. In Senegal, one of the most beautiful mangrove formations is located in the Saloum Delta. It contributes to the socio-economic enrichment of the area. This estuarine complex of major ecological importance is characterized by a mosaic of habitats subjected to strong environmental variations [2]. In these environments, the distribution of macrobenthic fauna is determined by a number of factors such as the physical nature of the substrate, depth, nutrient content, degree of stability, salinity, vegetation cover, and the oxygen content of interstitial water [3, 4].

Among these characteristic mangrove organisms, the fiddler crab *Afruca tangeri* (Eydoux, 1835) (Crustaceans, Decapods, Ocypodidae) occupies a central place. This species is widely recognized as an ecosystem engineer due to its bioturbation activity, which significantly alters the biogeochemical properties of sediments [5-7] and promotes oxidation processes, nutrient availability, and the development of bacterial and algal communities [8-15]. Crabs also contribute to the transfer of biomass to the sediments thru the deposition of exuviae and feces, potentially participating in the storage of carbon, nitrogen, iron, and sulfur; although this process remains insufficiently quantified [5, 16-19]. The digging of burrows also facilitates the removal of toxic substances and alters the redox state of the surrounding sediments [14, 20, 21]. Moreover, bioturbation alters the pH, salinity, and moisture of the sediments, changing the environment on a microscopic scale [22].

The Saloum Delta National Park (PNDS) is home to three main types of vegetation, including the amphibious domain, which consists of mangroves structured by (bare zone, *Avicennia*, and *Rhizophora*), each characterized by specific edaphic and hydrological conditions [23, 24]. These environmental gradients are likely to influence the spatial distribution and density of *Afruca tangeri* populations. However, despite the ecological importance of this species, few studies have thoroughly explored the influence of the physicochemical parameters of interstitial waters on its distribution in the various mangroves in West Africa, particularly in Senegal.

In this context, the present study aims to analyze the influence of the physicochemical parameters of interstitial waters on the distribution of *Afruca tangeri* within the three mangrove belts of the Saloum Delta National Park. More specifically, the aim is to (i) characterize the spatial variations of environmental parameters, (ii) evaluate the structure and density of *Afruca tangeri* populations, and (iii) determine the relationships between these variables in order to better understand the ecological mechanisms governing the distribution of this species in the PNDS mangroves.

2. Methodology

2.1. Study Area

The monthly sampling from August 2023 to July 2024 was conducted during low tide in the mangrove ecosystems of the PNDS located in the Fatick region of Senegal (between 13 °35 and 14 °15 North Latitude and 16 °03 and 16 °50 West Longitude). Three villages were selected for this study: Bakadadji (13°39’; 16°29’), Missirah (13°40’; 16°30’), and Bettenty (13°40’; 16°37’) (Figure 1), chosen based on their proximity to the mangrove ecosystems and the fact that almost the entire local population depends on these environments for their socio-economic activities. The villages of Missirah and Bettenty exhibit strong anthropogenic pressure on the mangroves, mainly due to overfishing, logging, and the disposal of domestic waste, making them particularly interesting areas to assess the impact of these disturbances on *Afruca tangeri* populations. In contrast, Bakadadji is located in a less disturbed area, closer to the heart of the Saloum Delta National Park (PNDS), and thus serves as an ecological reference site. In each village, two stations were selected based on (i) the probability of exposure to human activities and (ii) their geographical position, allowing for the capture of spatial variability representative of the anthropization gradient observed between the periphery of the protected area and the more natural zones. The sites were chosen according to the name of the village differentiated by the numbers 1 and 2 (for example: Bakadadji 1 (13°38’51.4’’N and 16°29’44.8’’W); Bakadadji 2 (13°38’02.0’’N and 16°29’47.2’’W).

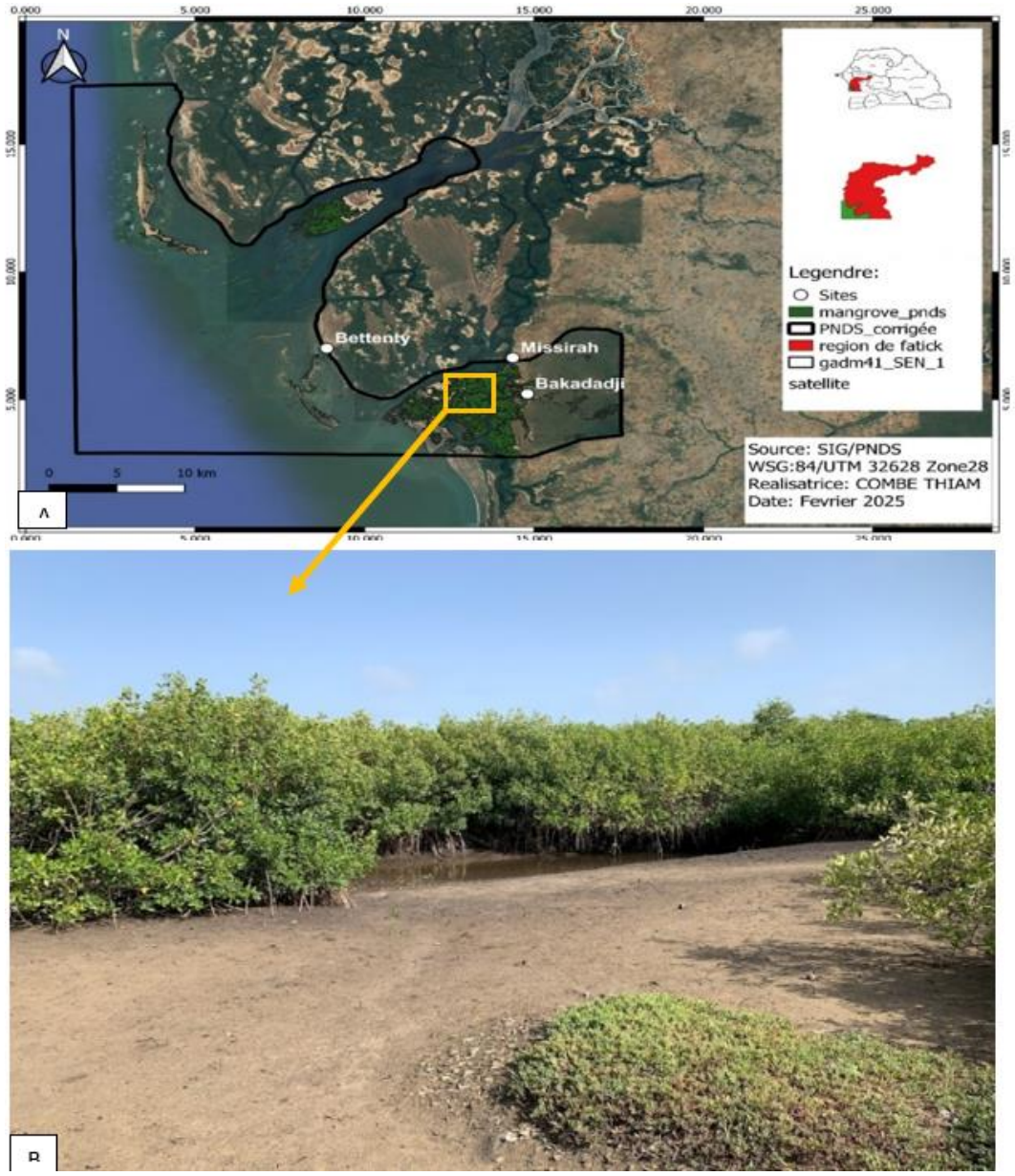


Figure 1. *A. Map of the PNDS showing the collection sites (Bakadadji, Missirah, and Bettenty) B. Collection site in Bakadadji (Thiam, 2023).*

2.2. Sampling

It primarily involves a reconnaissance visit to identify and locate the sites frequented by *A. tangeri* and the points for installing piezometers. Field outings were only possible during low tide. At each site, 3 transects of 50 meters in length were carried out according to the plant distribution and the characteristics of the sediments in the area. The first transect was placed on the belt of vegetation composed of *Rhizophora*, which is the minimum water level limit. The third transect was placed on the band of *Avicennia* and seagrass beds, and the second on the bare part devoid of vegetation located between the two belts. On each transect, an area of $1m^2$ will be delineated (quadrat) and subdivided into four sub-quadrats of $0.25m^2$ placed at equal distances of 10 meters along the transect. Each time, our study area was framed at two tidal levels (the lower limit of low tide and the upper limit of high tide).

2.3. Counting the Burrows

The estimation of the Uca population density is done using various methods with these shortcomings [25]. According to the work of [26], the burrows are strictly individual, and only rare exceptions of cohabitation are noted during the breeding period. In this study, we chose to count the burrows, which has been used by several authors to estimate the abundance of fiddler crabs [27-30]. The population density of *Afruca tangeri* estimated by burrow counting did not differ significantly from that estimated by excavation, while the density estimated by visual counting was significantly lower than the absolute

density but may sometimes indicate an overestimation of the population. The estimation of the number of individuals per mangrove zone was carried out using the indirect method [31, 32]. This method is more appropriate for clay-silt mangrove ecosystems as it does not destroy the environment. It is non-invasive and time-efficient, and can provide evidence of the size and density of the crab population thru measurements of burrow width and distribution [33]. This method, however, is subject to variable biases. The density of burrows of the *Afruca tangeri* population was counted in 0.25 m^2 sub-squares of each transect, and the diameter of the burrow openings was measured.

2.4. Physicochemical Parameters of Interstitial Waters in Burrows

A one-meter core was taken using an auger at each site. Instead of the cores, a piezometer was installed to collect interstitial waters by percolation. The physicochemical characteristics such as temperature, salinity, pH, dissolved oxygen, and electrical conductivity were analyzed on-site using a GPS Aqua multi-parameter probe in the first 30 centimeters of depth. The interstitial waters in the burrows were also measured.

2.5. Statistical Analysis

The statistical analyses were performed using Excel 2013, RStudio, and Python.

3. Results

3.1. Physicochemical Parameters of Interstitial Waters in Burrows

3.1.1. Correlation Matrix

The correlation matrix highlights strong and structuring relationships between the physicochemical parameters of interstitial waters (Figure 2). Our results showed that temperature is strongly and positively correlated with pH (r = 0.84) and electrical conductivity (r = 0.66). The pH shows a very high correlation with electrical conductivity (r = 0.96). Conversely, dissolved oxygen is strongly and negatively correlated with pH (r = −0.73) and especially with conductivity (r = −0.89). On the other hand, salinity shows a marked positive correlation with dissolved oxygen (r = 0.74).

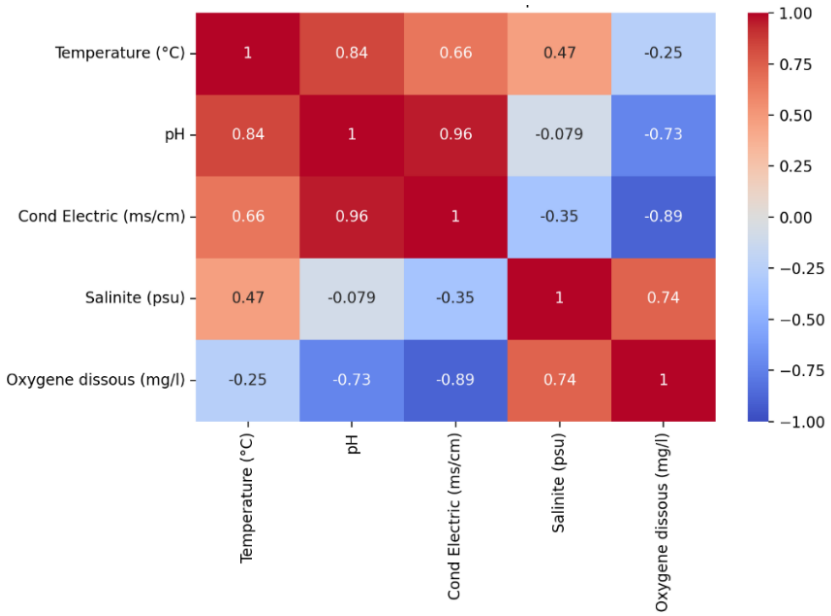


Figure 2. *Correlation matrix of the physicochemical parameters of interstitial water in burrows.*

3.1.2. Physicochemical Parameters of Interstitial Waters in *A. tangeri* Burrows According to Belts

Figure 3 shows the average values of the physicochemical parameters of the interstitial waters of the burrows comparable between the belts (*Avicennia*, *Rhizophora*, and bare zone) in the PNDS. The temperature is similar among the three belts, with values around 30 ℃. The pH varies slightly and generally remains between slightly acidic to neutral values (6.93 – 7.09). Electrical conductivity (EC) shows clear differences between the belts. The highest values are recorded in the bare zone (89.67 ms/cm), followed by the *Avicennia* belt (75.98 ms/cm), while the lowest values are observed under *Rhizophora* (58.13 ms/cm). Salinity also shows variations between the belts and

sites, with higher values under *Avicennia* (26.58 psu) and under *Rhizophora* (24.93 psu), and slightly lower values in the bare zone (22.96 psu). The concentrations of dissolved oxygen (DO) are low across all belts, with slightly higher values under *Rhizophora* (1.78) compared to the *Avicennia* belts and the bare zone. The Kruskal-Wallis tests reveal that the differences in physicochemical parameters are not significant ($p > 0.05$) between the belts (Table 1).

The spider chart highlights distinct physicochemical profiles for each belt, primarily characterized by variations in electrical conductivity, salinity, and dissolved oxygen.

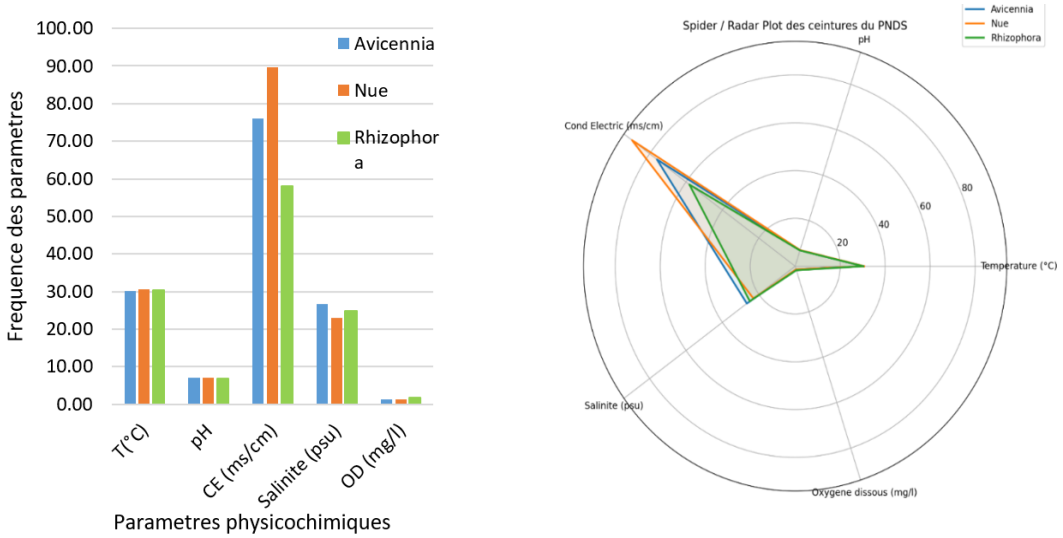


Figure 3. *Histogram (a), spider web plot (b) of the parameters of the interstitial water in burrows by belt.*

Table 1. *Kruskal-Wallis test (K^2) for physicochemical parameters across the belts.*

PC	Ceinture	K^2	df	p-value	Signif	Method
T	Av – Nue - Rh	1,1556	2	0,5611	ns	Kruskal-Wallis
pH	Av – Nue - Rh	1,4118	2	0,4937	ns	Kruskal-Wallis
CE	Av – Nue - Rh	1,8667	2	0,3932	ns	Kruskal-Wallis
Sal	Av – Nue - Rh	0,26667	2	0,26667	ns	Kruskal-Wallis
O2 dissous	Av – Nue - Rh	0,08889	2	0,9565	ns	Kruskal-Wallis

3.1.3. Physicochemical Parameters of Interstitial Waters in Burrows According to Sites

Figure 4 shows the average values of the physicochemical parameters of interstitial waters in the burrows according to the sampling sites (Bakadadji, Bettenty, and Missirah) in the PNDS. The temperature is similar between the three sites, with values around 30 ℃. The pH varies slightly and generally remains between slightly acidic to neutral values (6.87 – 7.23). Electrical conductivity (EC) shows differences between the sites. The highest values are recorded at Missirah (88.01 ms/cm), followed by Bettenty (76.71 ms/cm), while the lowest values are observed at Bakadadji (59.06 ms/cm). Salinity also shows variations between the belts and the sites, with higher values at Bakadadji (30.41 psu) and Missirah (18.40 psu), and slightly lower values at Bettenty (17.23 psu). The concentrations of dissolved oxygen (DO) are low across all belts, with slightly lower values at Bettenty (0.89 mg/l) compared to the Missirah and Bakadadji sites. The Kruskal-Wallis tests reveal that the differences in physicochemical parameters are not significant ($p > 0.05$) between the belts except for salinity, which is very significant ($p < 0.05$) (Table 2).

The spider chart highlights distinct physicochemical profiles for each site, primarily characterized by variations in electrical conductivity, salinity, and dissolved oxygen.

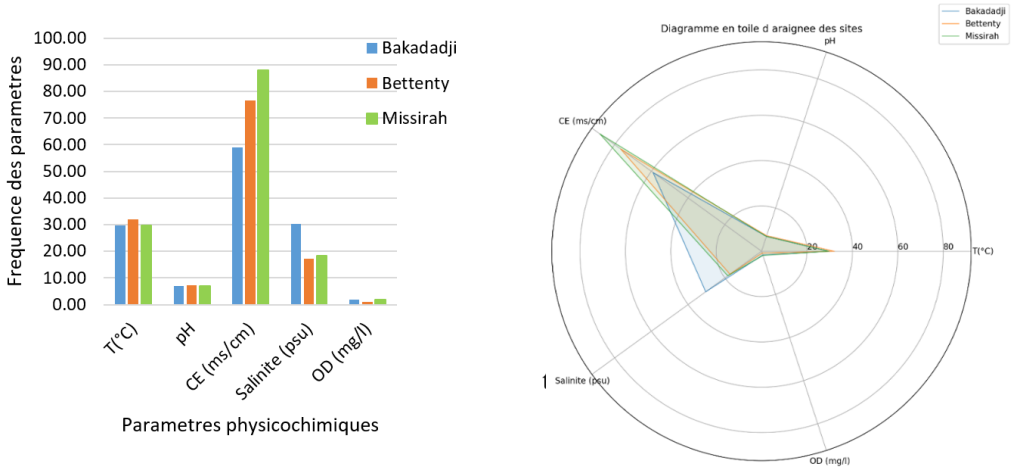


Figure 4. *Histogram (c), spider web plot (d) of interstitial water parameters from Afruca tangeri burrows by site.*

Table 2. *Kruskal-Wallis test (K^2) for physicochemical parameters across sites.*

PC	Site	K^2	df	p-value	Signif	Method
T	Bd – Bt - M	5,4222	2	0,06646	ns	Kruskal-Wallis
pH	Bd – Bt - M	3,3165	2	0,1905	ns	Kruskal-Wallis
CE	Bd – Bt - M	2,4	2	0,3012	ns	Kruskal-Wallis
Sal	Bd – Bt - M	6,4889	2	0,0399	*	Kruskal-Wallis
O2 dissous	Bd – Bt - M	4,2667	2	0,1184	ns	Kruskal-Wallis

3.2. Density

3.2.1. Density According to Sites

The results show that the average density of *Afruca tangeri* varies significantly among the sites and mangrove belts studied in the Saloum Delta National Park. The average density is 63.02 ind/m^2 in the PNDS. The highest densities were observed at Bakadadji (68.67 ind/m^2) and Missirah (67.60 ind/m^2), while Bettenty recorded the lowest values (52.80 ind/m^2). The Kruskal-Wallis test (K^2 = 2, df = 2, p-value = 0.3679) shows that density does not differ significantly among the sites (Figure 5).

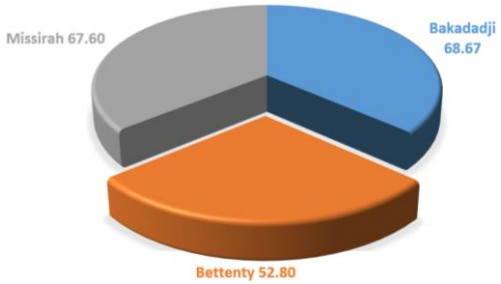


Figure 5. *Individual Density by Site.*

3.2.2. Density According to Belts

The results show that the average population density of *Afruca tangeri* varies significantly across mangrove belts. It is highest under *Rhizophora* (100 ind/m^2), intermediate under *Avicennia* (71.7 ind/m^2), and lowest in the bare area (49.1 ind/m^2) (Figure 6). The Kruskal–Wallis test (K^2 = 17.767; df = 2; p = 0.0001 < 0.05) reveals a highly significant difference among the belts. The Wilcoxon post-hoc test specifies that the difference is significant between the bare zone and the *Rhizophora* zone (p = 0.0004), as well as between the *Avicennia* zone and the bare zone (p = 0.015). However, no significant difference was observed between the *Avicennia* and *Rhizophora* belts (p = 0.119) (Table 3).

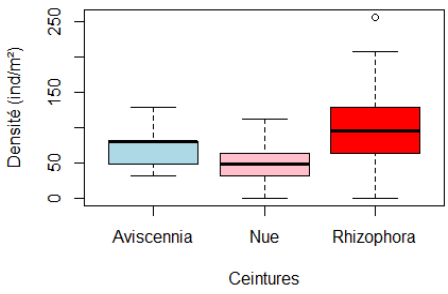


Figure 6. *Density of Afruca tangeri individuals by belt zone.*

Table 3. Wilcoxon post-hoc test. Density-belt.

Ceinture	Avicenia	Nue
Nue	0.01518	-
Rhizophoras	0.11980	0.00045

3.3. Density of *Afruca tangeri* in Relation to the Physico-chemical Parameters Measured at Different Sites

The Principal Component Analysis (PCA) conducted based on the density of individuals and the physicochemical parameters measured in the different belts of the Saloum Delta National Park highlights a clear representation of the relationships between environmental conditions and the spatial distribution of *Afruca tangeri*. The two dimensions of the factorial plane of the Principal Component Analysis (PCA) explain 73.36% of the total variability, with 48.8% by Dim 1 and 24.5% by Dim 2. This high proportion indicates a good quality of information representation by these two axs and a significant ecological structuring of the data. The points on the graph represent the different belts of the stations (*Rhizophora* Bd, *Avicennia* Bt, and Nue M) with a colorimetric scale indicating the gradient of the density of *Afruca tangeri* individuals in the belts, ranging from yellow (higher) to purple (lower). The red arrows symbolize the physicochemical parameters of the interstitial waters in the burrows, namely: Dissolved oxygen, Electrical conductivity (Cond Electric), pH, Salinity, and Temperature. The first dimension (Dim 1) is primarily defined by the physicochemical variables. pH and electrical conductivity contribute strongly and positively to Dim 1, while salinity and dissolved oxygen are negatively related to this dimension. The temperature is also positively linked to Dim 1 but with a lesser contribution. The *Rhizophora* Bd, *Rhizophora* M, *Avicennia* Bd, and *Avicennia* M belts, characterized by high densities, and Nue Bd with a low density, are strongly associated with high salinities and dissolved oxygen, while *Avicennia* Bt and Nue M, where the density is lower, are distinguished by high pH and conductivity values. The *Rhizophora* Bt belt, associated with high density, and the Nue Bt, with low density, are both correlated with relatively high temperatures (Figure 7).

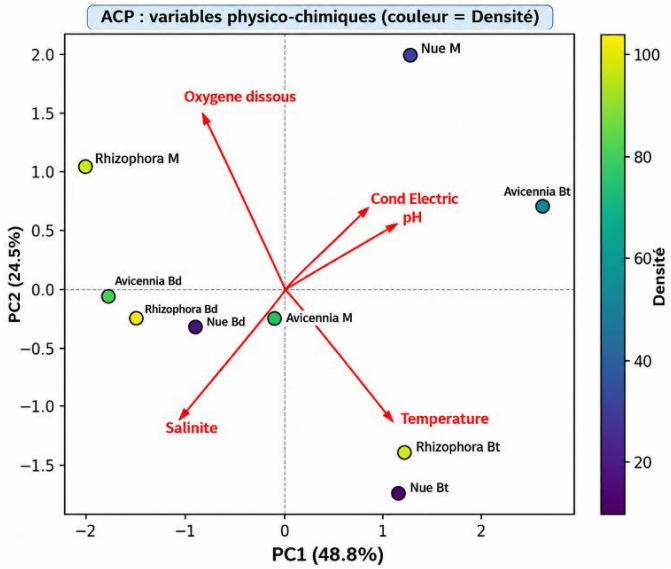


Figure 7. Density-dependent PCA of the physicochemical parameters (temperature, pH, electrical conductivity, salinity, dissolved oxygen) of the belts.

4. Discussion

The physicochemical parameters of the interstitial waters of *Afruca tangeri* burrows in the Saloum Delta National Park (PNDS) show values that are generally comparable between the mangrove belts (*Avicennia*, *Rhizophora*, and bare zone), with notable variations for certain key parameters. The temperature, close to 30 ℃ across all belts, reflects the Sahelian climatic context and the low thermal amplitude of interstitial waters in Senegalese mangroves, as reported in the Saloum Delta and the Casamance estuary [24, 34, 35]. These relatively high temperatures are characteristic of shallow tropical estuarine systems, strongly influenced by sunlight and tides.

The pH, with slight variability and ranging between slightly acidic and neutral values (6.93–7.09), is consistent with observations made in the mangroves of Saloum and Sine-Saloum. This could be explained by the processes of organic matter

decomposition, root respiration, and microbial activity, which tend to moderately acidify the interstitial waters [36, 37]. The values of our study differ from those of [38] which indicate that the pH fluctuates around neutrality with values ranging between 7.3 and 7.9 in the mangroves of the Saloum estuary. This low variability of pH between belts could be due to strong control by tidal exchanges and a chemical homogenization of shallow groundwater.

Electrical conductivity and salinity, on the other hand, show marked contrasts between the belts. The high conductivity values recorded in the bare zone indicate a strong ionic concentration linked to evaporation, the absence of vegetation cover, and direct exposure to climatic conditions, a phenomenon widely documented in the mudflats and bare areas of the Saloum delta [38-40]. In contrast, the lower values observed under *Rhizophora* reflect the buffering role of the vegetation, whose stilt roots promote water retention, salt dilution, and more frequent renewal of interstitial waters during tides [37, 41]. The salinity is higher under *Avicennia* (26.58 psu) than under *Rhizophora* (24.93). These results confirm those of [38, 42] which showed that *Rhizophora* are less tolerant to salinity than *Avicennia*. The higher salinity under the vegetation compared to the bare area can be explained by the combination of tidal exchanges and the selective absorption of water by the roots, which tends to concentrate salts in the surrounding sediments, a process well described in Senegalese and West African mangroves [7, 34]. These saline conditions directly influence the distribution and activity of burrowing crabs, among which *Afruca tangeri* is particularly tolerant to salinity variations. The low concentrations of dissolved oxygen observed throughout the belts, with slightly higher values under *Rhizophora*, are characteristic of mangrove interstitial waters, generally hypoxic to anoxic. This situation results from the high microbial respiration associated with the decomposition of organic matter and the low diffusion of oxygen in water-saturated fine sediments [37, 43]. The slightly higher values under *Rhizophora* can be attributed to intense bioturbation and the presence of aerial roots, which locally improve sediment aeration, as observed in Saloum and Casamance [7, 17, 44-46].

The physicochemical parameters of the interstitial waters of *Afruca tangeri* burrows are mainly characterized by variations in electrical conductivity, salinity, and dissolved oxygen between the sites of Bakadadji, Bettenty, and Missirah in the National Park of the Saloum Delta (PNDS). The high electrical conductivity values recorded at Missirah (88.01 ms/cm) and Bettenty (76.71 ms/cm) could be explained by the more confined conditions and significant evaporation, typical of the hypersaline areas of the Saloum Delta [34, 38]. Conversely, the lower values observed at Bakadadji (59.06 ms/cm) could be due to a more pronounced tidal influence or better hydraulic connectivity with the estuarine channels, as described by [40]. Salinity also shows notable spatial variability, with particularly high values at Bakadadji compared to other sites, which could be explained by a strong retention of interstitial waters associated with evaporation. Conversely, the salinity rate at Bettenty may be due to significant domestic discharges that can alter the salinity of mangrove ecosystems thru the dilution of interstitial waters. The slightly lower DO values observed at Bettenty could reflect a lower renewal of interstitial waters or a higher oxygen consumption related to local biological activity, as documented in the mangroves of Saloum and Casamance [34, 40].

In the present study, the average density of the *Afruca tangeri* population is estimated at 63.02 ind/m^2 in the Saloum Delta National Park (PNDS). This value is significantly higher than those reported by several previous studies. Indeed, [47] estimated average densities of 1.3 ind/m^2 in Saint-Louis, 1.5 ind/m^2 in Saloum, and 1.6 ind/m^2 in Casamance. Similarly, [48] reported densities of 1.8 ind/m^2 at Dionewar and 1.6 ind/m^2 at Sounil, in the Fadiouth lagoon. Furthermore, [26] estimated a density of 17 ind/m^2 for *A. tangeri* in the Ria Formosa lagoon (Portugal), based on burrow counts. The strong variation observed between the density estimates of *A. tangeri* could be largely explained by the absence of a standardized sampling protocol capable of reducing biases associated with indirect methods. In this context, density estimates can be strongly influenced by several methodological factors, including the size of the sampling quadrat and the targeted mangrove area during sampling.

On the other hand, our results align with those reported by [49], who highlighted high burrow densities in *Uca chlorophthalmus, U. sindensis, and U. annulipes*, respectively 145.1 ± 80.5, 98.7 ± 52.5, and 74.5 ± 31.0 ind/m^2, along the coasts of Pakistan. Similarly, [50] found an average density of 24.89 ind/m^2 for species of the genus *Uca* in the Kema mangrove, in northern Sulawesi (Indonesia). Furthermore, for *Uca annulipes*, average densities of 18.5 ind/m^2 and 17.5 ind/m^2 were recorded respectively during the spring tide and low tide in the Mida Creek, Kenya [30]. However, significantly lower densities have been reported for *Uca cordatus*, with an average of 1.32 ± 0.90 ind/m^2 in the mangroves of Todos Santos Bay (Bahia, Brazil) [51, 52]. The differences in density observed between *A. tangeri* and other species of the genus *Uca* can be attributed to several ecological factors. Among these are interspecific competition [4], intraspecific competition [53], or the combination of both, as well as the availability and nature of food resources [54-56]. Other environmental factors, such as the level of tide-related flooding [57, 58] and salinity [59, 60], also play a crucial role in the spatial structuring and density of Uca populations.

The density of *Afruca tangeri* varies in terms of numbers between the studied sites. It is higher at Bakadadji (68.67 ind/m^2) and Missirah (67.60 ind/m^2) than at Bettenty, although this difference is not statistically significant according to the Kruskal-Wallis test ($p > 0.05$). These spatial changes could be influenced by local environmental conditions and the structure of mangrove habitats on the distribution and abundance of the species. Indeed, several studies have shown that species of the genus *Uca* exhibit a marked preference for substrates.

Within the sites, the *Rhizophora* belt exhibits the highest

densities of *Afruca tangeri*, followed by that of *Avicennia*, while bare areas record the lowest values. These observations align with the work of [61], which showed that the densities of *Uca spinicarpa* and *Uca longisignalis* burrows were higher in vegetated areas than in sparsely or non-vegetated areas. The density of *Afruca tangeri* is directly affected by the natural characteristics of mangrove areas, such as the composition of the tree vegetation [58]. In the mangroves of the Wouri River estuary in Cameroon [62], it is indicated that the number of crab species is positively correlated with the vegetation and that the area with *Rhizophora* spp is associated with the high abundance (26.52%) of crab species. on the contrary This spatial distribution reflects the strong ecological dependence of fiddler crabs on the structure and complexity of their habitat. Indeed, *Rhizophora* stands offer a muddy, humid substrate rich in organic matter, ideal for burrowing and constructing burrows [10, 11]. The stilt roots of mangroves help keep fine sediments and stabilize the soil, creating a good place to find food and protection from predators [17]. Intraspecific competition can also play a role in structuring local densities. In favorable habitats, individuals tend to cluster until they reach a maximum density compatible with the availability of resources and space for burrows [53]. On the other hand, when conditions become limiting, the density decreases in favor of a more dispersed spatial occupation. On the other hand, bare areas, often subjected to severe desiccation and difficult conditions (temperature fluctuations) and extreme variations in salinity, present less favorable conditions for crab settlement. These exposed environments limit the availability of organic matter and the possibility of digging stable burrows, hence the low density observed [63, 64]. *Avicennia* tolerate salt better, but their soil is sandier and less rich in organic matter than that of *Rhizophora*, which explains why there are fewer crabs than in *Rhizophora* [65]. These trends are consistent with several studies conducted in the tropical mangroves of West Africa and elsewhere, which show that *Afruca tangeri* prefers areas with fine sediments, rich in detritus, and moderately flooded [66-69]. Thus, the variation in densities according to the vegetation belts reflects an ecological gradient of habitat quality, where the density of *Afruca tangeri* can be used as a reliable bio-indicator of the health of mangrove ecosystems [11, 30, 70], The ecological functions of benthic faunal communities and their distributions are strongly dependent on environmental factors of the habitat [71-73]. The Biplot PCA shows that the variation in the population density of *A. tangeri* in the belts depends on the physicochemical parameters of the environment. These relationships are consistent with the scientific literature on aquatic systems where physicochemical parameters strongly influence biotic composition and the distribution of organisms [74] and similarly in studies in aquatic ecology and environmental sciences [75]. The species *Afruca tangeri* exhibits higher densities in the belts (*Rhizophora* Bd and M, *Avicennia* Bd and M) characterized by significant salinity and dissolved oxygen (DO) levels. Conversely, it is less abundant in areas (*Avicennia* Bt and Nue M) marked by high conductivity and pH, indicating more constrained environments. Our results corroborate the studies of [73], which highlight the significant role of water temperature and particularly DO in structuring the diversity and abundance of benthic species in Nigerian tropical coastal wetlands. Conversely, these authors show that conductivity and pH have only a weak influence on this abundance. Salinity has also been proposed as a major factor controlling the distribution of crabs in the Persian Gulf, particularly for Uca species [76]. According to the study by [77] on the coast of Huelva, Spain, the parameters (temperature and pH) do not influence the density of *Afruca tangeri* in the study areas.

5. Conclusion

This study demonstrates that the distribution of *Afruca tangeri* in the mangroves of the Saloum Delta National Park is primarily driven by environmental conditions, particularly salinity. While temperature and pH remained relatively stable across sites, salinity was identified as the key factor influencing the species spatial distribution. The highest densities were recorded in *Rhizophora* stands, indicating a preference for this habitat. These findings highlight the value of *A. tangeri* as a bioindicator of mangrove ecological condition and provide useful information for the conservation and management of these ecosystems.

Abbreviations

PNDS	Saloum Delta National Park
Bd	Bakadadji
M	Missirah
Bt	Bettenty

Acknowledgments

I would like to express my sincere thanks to Professor Serigne Modou Sarr and Professor Youssouph Diatta for their invaluable contribution to the success of this project. I would also like to thank the PNDS staff and the technicians at the wastewater treatment laboratory (LATEU-IFAN).

Author Contributions

Combe Thiam: Conceptualization, Formal Analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing

Serigne Modou Sarr: Resources, Supervision, Validation

Youssouph Diatta: Supervision

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] A. O. Lawal-Are & H. Nwankwo, «Biology of the Hairy Mangrove Crab, Sersema huzardii (Decapoda: Graspidae) from a Tropical Estuarine Lagoon », *Journal of American Science*, vol. 7, nº 7, p. 402-408, 2011.

[2] P. S. Diouf, "The Fish Populations of the Estuarine Environments of West Africa: The Example of the Hyperhaline Si-n é-Saloum Estuary," Thesis and Microfiche Documents, Office of Scientific and Technical Research Overseas (ORSTOM), Paris, 1996.

[3] I. K. Esenowo & A. A. A. Ugwumba, « Composition and Abundance of Macrobenthos in Majidun River, Ikorordu Lagos State, Nigeria », *Research J. of Biological Sciences*, vol. 5, nº 8, p. 556-560, 2010, https://doi.org/10.3923/rjbsci.2010.556.560.

[4] J. M. Teal, «Respiration of Crabs in Georgia Salt Marshes and Its Relation to Their Ecology », *Physiological Zoology*, vol. 32, nº 1, p. 1-14, 1959, https://doi.org/10.1086/physzool.32.1.30152287

[5] E. Fanjul, M. C. Bazterrica, M. Escapa, M. A. Grela, & O. Iribarne, «Impact of crab bioturbation on benthic flux and nitrogen dynamics of Southwest Atlantic intertidal marshes and mudflats », *Estuarine, Coastal and Shelf Science*, vol. 92, nº 4, p. 629-638, 2011, https://doi.org/10.1016/j.ecss.2011.03.002

[6] G. Holguin, P. Vazquez, & Y. Bashan, «The role of sediment microorganisms in the productivity, conservation, and rehabilitation of mangrove ecosystems: an overview », *Biol Fertil Soils*, vol. 33, nº 4, p. 265-278, 2001, https://doi.org/10.1007/s003740000319

[7] E. Kristensen, S. Bouillon, T. Dittmar, & C. Marchand, «Organic carbon dynamics in mangrove ecosystems: A review », *Aquatic Botany*, vol. 89, nº 2, p. 201-219, 2008, https://doi.org/10.1016/j.aquabot.2007.12.005

[8] D. M. Alongi, «Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change », *Estuarine, Coastal and Shelf Science*, vol. 76, nº 1, p. 1-13, 2008, https://doi.org/10.1016/j.ecss.2007.08.024

[9] F. Bartolini, F. Cimò, M. Fusi, F. Dahdouh-Guebas, G. P. Lopes, & S. Cannicci, «The effect of sewage discharge on the ecosystem engineering activities of two East African fiddler crab species: Consequences for mangrove ecosystem functioning », *Marine Environmental Research*, vol. 71, nº 1, p. 53-61, 2011, https://doi.org/10.1016/j.marenvres.2010.10.002

[10] S. Cannicci, D. Burrows, S. Fratini, T. J. Smith, J. Offenberg, & F. Dahdouh-Guebas, «Faunal impact on vegetation structure and ecosystem function in mangrove forests: A review », *Aquatic Botany*, vol. 89, nº 2, p. 186-200, 2008, https://doi.org/10.1016/j.aquabot.2008.01.009

[11] E. Kristensen, «Mangrove crabs as ecosystem engineers; with emphasis on sediment processes », *Journal of Sea Research*, vol. 59, nº 1-2, p. 30-43, 2008, https://doi.org/10.1016/j.seares.2007.05.004

[12] E. Kristensen, G. Penha-Lopes, M. Delefosse, T. Valdemarsen, C. Quintana, & G. Banta, «What is bioturbation? The need for a precise definition for fauna in aquatic sciences », *Mar. Ecol. Prog. Ser.*, vol. 446, p. 285-302, 2012, https://doi.org/10.3354/meps09506

[13] E. Kristensen & D. M. Alongi, «Control by fiddler crabs (Uca vocans) and plant roots (Avicennia marina) on carbon, iron, and sulfur biogeochemistry in mangrove sediment », *Limnology and Oceanography*, vol. 51, nº 4, p. 1557-1571, 2006, https://doi.org/10.4319/lo.2006.51.4.1557

[14] S. Y. Lee, «Ecological role of grapsid crabs in mangrove ecosystems: a review », *Mar. Freshwater Res.*, vol. 49, nº 4, p. 335, 1998, https://doi.org/10.1071/MF97179

[15] T. Xie *et al.*, «Potential Effect of Bioturbation by Burrowing Crabs on Sediment Parameters in Coastal Salt Marshes », *Wetlands*, vol. 40, nº 6, p. 2775-2784,. 2020, https://doi.org/10.1007/s13157-020-01341-1

[16] D. M. Alongi, « Present state and future of the world's mangrove forests », *Environmental Conservation*, vol. 29, nº 3, p. 331-349, 2002, https://doi.org/10.1017/S0376892902000231

[17] D. M. Alongi, Ed., «The Forest Floor », in *The Energetics of Mangrove Forests*, Dordrecht: Springer Netherlands, 2009, p. 89-127. https://doi.org/10.1007/978-1-4020-4271-3_5

[18] A. C. Ferreira, L. E. A. Bezerra, & H. Matthews-Cascon, « Aboveground carbon stock in a restored neotropical mangrove: influence of management and brachyuran crab assemblage », *Wetlands Ecol Manage*, vol. 27, nº 2, p. 223-242, juin 2019, https://doi.org/10.1007/s11273-019-09654-7

[19] J. Q. Wang *et al.*, «Bioturbation of Burrowing Crabs Promotes Sediment Turnover and Carbon and Nitrogen Movements in an Estuarine Salt Marsh », *Ecosystems*, vol. 13, nº 4, p. 586-599, 2010, https://doi.org/10.1007/s10021-010-9342-5

[20] S. S. L. Lim & C. H. Diong, «Burrow-Morphological Characters of the Fiddler Crab, *Uca annulipes* (H. Milne Edwards, 1837) and Ecological Correlates in a Lagoonal Beach on Pulau Hantu, Singapore », *Crustaceana*, vol. 76, nº 9, p. 1055-1069, 2003.

[21] I. Nagelkerken *et al.*, «The habitat function of mangroves for terrestrial and marine fauna: A review », *Aquatic Botany*, vol. 89, nº 2, p. 155-185, 2008, https://doi.org/10.1016/j.aquabot.2007.12.007

[22] Y. Yang, Q. Liang, Y. Peng, & D. M. Paterson, «Differential mediation of biogeochemical processes through bioturbation by fiddler and sesarmid mangrove crabs », *Marine Pollution Bulletin*, vol. 211, p. 117431, 2025, https://doi.org/10.1016/j.marpolbul.2024.117431

[23] A. B. Diop *et al.*, «Characterization of the Saloum Mangrove, Senegal », *ResearchGate*, vol. 8, nº 2, p. 57-66, 2023.

[24] PAG PNDS, « Plan d'Amenagement et de Gestion du Parc National du Delta du Saloum (PNDS) 2021-2025 », Centre de Suivi Ecologique, 2021.

[25] D. R. Colby & M. S. Fonseca, « Population dynamics, spatial dispersion and somatic growth of the sand fiddler crab Uca pugilator », *Marine Ecology Progress Series*, vol. 16, nº 3, p. 269-279, 1984.

[26] B. Wolfrath, « Field experiments on feeding of European fiddler crab Uca tangeri », *Marine Ecology Progress Series*, vol. 90, nº 1, p. 39-43, 1992.

[27] J. M. Jordão & R. F. Oliveira, « Comparison of non-invasive methods for quantifying population density of the fiddler crab *Uca tangeri* », *J. Mar. Biol. Ass.*, vol. 83, nº 5, p. 981-982, oct. 2003, https://doi.org/10.1017/S002531540300818Xh

[28] A. Macia, I. Quincardete, & J. Paula, « A comparison of alternative methods for estimating population density of the fiddler crab Uca annulipes at Saco Mangrove, Inhaca Island (Mozambique) », in *Advances in Decapod Crustacean Research*, J. P. M. Paula, A. A. V. Flores, et C. H. J. M. Fransen, Ed., Dordrecht: Springer Netherlands, 2001, p. 213-219. https://doi.org/10.1007/978-94-017-0645-2_23

[29] E. C. Mouton & D. L. Felder, « Burrow distributions and population estimates for the fiddler crabsUca spinicarpa andUca longisignalis in a Gulf of Mexico salt marsh », *Estuaries*, vol. 19, nº 1, p. 51-61, mars 1996, https://doi.org/10.2307/1352651

[30] M. Skov, M. Vannini, J. Shunula, R. Hartnoll, & S. Cannicci, « Quantifying the density of mangrove crabs: Ocypodidae and Grapsidae », *Marine Biology*, vol. 141, nº 4, p. 725-732, oct. 2002, https://doi.org/10.1007/s00227-002-0867-9

[31] M. A. A. Pinheiro, L. F. A. Duarte, T. R. Toledo, M. L. Adam,& R. A. Torres, « Habitat monitoring and genotoxicity in Ucides cordatus (Crustacea: Ucididae), as tools to manage a mangrove reserve in southeastern Brazil », *Environ Monit Assess*, vol. 185, nº 10, p. 8273-8285, oct. 2013, https://doi.org/10.1007/s10661-013-3172-9

[32] A. C. Wunderlich, M. A. A. Pinheiro, & A. M. T. Rodrigues, « Biologia do caranguejo-uçá, Ucides cordatus (Crustacea: Decapoda: Brachyura), na Baía da Babitonga, Santa Catarina, Brasil », *Rev. Bras. Zool.*, vol. 25, p. 188-198, 2008, https://doi.org/10.1590/S0101-81752008000200005

[33] M. W. Skov et R. G. Hartnoll, «Comparative suitability of binocular observation, burrow counting and excavation for the quantification of the mangrove fiddler crab Uca annulipes (H. Milne Edwards) », in *Advances in Decapod Crustacean Research*, J. P. M. Paula, A. A. V. Flores, & C. H. J. M. Fransen, Ed., Dordrecht: Springer Netherlands, 2001, p. 201-212. https://doi.org/10.1007/978-94-017-0645-2_22

[34] E. S. Diop, I. Ndour, & M. C. Cormier-Salem, *Estuaires Et Mangroves d'Afrique De l'Ouest*. IRD Editions, 2014.

[35] I. Sakho, V. Mesnage, J. Deloffre, R. Lafite, I. Niang, & G. Faye, « The influence of natural and anthropogenic factors on mangrove dynamics over 60 years: The Somone Estuary, Senegal », *Estuarine, Coastal and Shelf Science*, vol. 94, nº 1, p. 93-101, 2011, https://doi.org/10.1016/j.ecss.2011.05.032

[36] N. M. Dieng, «Study of the relationship between surface water and groundwater in the context of climate change in the southern zone of the lower Saloum basin (Senegal), Doctoral Thesis, Cheikh Anta Diop University of Dakar (UCAD), Senegal, 2017. https://orbi.uliege.be/handle/2268/215408

[37] C. Marchand, F. Baltzer, E. Lallier-Verges, & P. Alberic, « Pore-water chemistry in mangrove sediments: relationship with species composition and developmental stages (French Guiana) », *Marine Geology*, vol. 208, nº 2, p. 361-381, 2004, https://doi.org/10.1016/j.margeo.2004.04.015

[38] A. Guisse, M. N. Faye, & N. Diallo, «Influence of pH, water salinity, and soil texture on the vegetation of the mangrove in the Saloum estuary in Senegal », *Journal of Sciences and Technologies*, vol. 5, nº 1, p. 8-17, 2007.

[39] S. Diop, "The West African Coast: from Saloum (Senegal) to Mellacorée (Republic of Guinea)," State Doctorate Thesis, Louis Pasteur University, Strasbourg, France, 1990.

[40] B. Faye, « Dynamics and detection of land use changes in the northern part of the Saloum estuary from 1973 to 2014 », *Revue Marocaine de Géomorphologie*, nº 2, 2018, https://revues.imist.ma/index.php/Remageom/article/view/10566

[41] E. J. Anthony, R. Almar, T. Aagaard, & S. G. Jensen, « Recent shoreline changes and coastal dynamics along the West African coast », *Journal of Coastal Research*, vol. 35, nº 5, p. 1050-1063, 2019.

[42] L. Morrow & N. H. Nickerson, « Concentrations de sel dans les eaux souterraines sous Rhizophora mangle et Avicennia germinans », *Rhodora*, vol. 75, nº 801, p. 102-106, 1973.

[43] E. Kristensen, « Organic matter diagenesis at the oxic/anoxic interface in coastal marine sediments, with emphasis on the role of burrowing animals », in *Life at Interfaces and Under Extreme Conditions*, G. Liebezeit, S. Dittmann, et I. Kröncke, Ed., Dordrecht: Springer Netherlands, 2000, p. 1-24. https://doi.org/10.1007/978-94-011-4148-2_1

[44] F. Botto, I. Valiela, O. Iribarne, P. Martinetto, & J. Alberti, « Impact of burrowing crabs on C and N sources, control, and transformations in sediments andfood webs of SW Atlantic estuaries », *Marine Ecology Progress Series*, vol. 293, p. 155-164, juin 2005, https://doi.org/10.3354/meps293155

[45] J. M. Ecoutin & P. S. Diouf, « The Saloum estuary (Senegal): a hypersaline ecosystem. In : C. H. R. Heip, P. M. J. Herman & J. J. Middelburg (Eds.), The West African Marine Ecoregion », *Ocean & Coastal Management*, vol. 46, nº 1-2, p. 183-200, 2003.

[46] S. Sarker, M. Masud-Ul-Alam, M. S. Hossain, S. Rahman Chowdhury, & S. Sharifuzzaman, « A review of bioturbation and sediment organic geochemistry in mangroves », *Geological Journal*, vol. 56, nº 5, p. 2439-2450, 2021, https://doi.org/10.1002/gj.3808

[47] L. S. Manga, A. Faye, J. Fall, et M. Diouf, «Size class, density, and distribution of Uca tangeri (Eydoux, 1835; Decapoda: Ocypodidae) in the mangrove ecosystems of Senegal », *Int. J. Fish. Aquat. Stud.*, vol. 11, nº 1, p. 133-140, janv. 2023, https://doi.org/10.22271/fish.2023.v11.i1b.2776

[48] P. S. Diouf, T. Bousso, H. D. Diadhiou, & M. Kebe, "The Fisheries in the Estuaries of Senegal," in Coastal and Marine Resource Management in Senegal, Proceedings of the Gorée Workshop, Senegal, 1992, p. 27-29.

[49] N. A. Qureshi et N. U. Saher, « Burrow morphology of three species of fiddler crab (Uca) along the coast of Pakistan », *Belg. J. Zool.*, vol. 142, nº 2, p. 114-126, 2012, https://doi.org/10.26496/bjz.2012.152

[50] P. Rianta, W. Ernawati, G. Chen, & S. Chen, « Diversity and abundance of mangrove fiddle crabs, genus Uca (Decapoda, Ocypodidae) at a mangrove in Kema, North Sulawesi, Indonesia », *Acta Oceanol. Sin.*, vol. 37, nº 12, p. 92-96, 2018, https://doi.org/10.1007/s13131-018-1336-8

[51] T. A. Mota, M. A. A. Pinheiro, N. S. Evangelista-Barreto, & S. S. Da Rocha, « Density and extractive potential of "uça"-crab, Ucides cordatus (Linnaeus, 1763), in mangroves of the "Todos os Santos" Bay, Bahia, Brazil », *Fisheries Research*, vol. 265, p. 106733, sept. 2023, https://doi.org/10.1016/j.fishres.2023.106733

[52] M. A. A. Pinheiro *et al.*, « Advances in population monitoring of the mangrove 'uça'-crab (Ucides cordatus): reduction of body size variance for better evaluation of population structure and extractive potential », *Marine Biology Research*, vol. 19, nº 2-3, p. 141-153, 2023, https://doi.org/10.1080/17451000.2023.2205148

[53] J. Crane, *Fiddler Crabs of the World OCYPODDAE: GENUS UCA*. Princeton University Press, 1975.

[54] R. A. Christofoletti, G. Y. Hattori, & M. A. A. Pinheiro, «Food selection by a mangrove crab: temporal changes in fasted animals », *Hydrobiologia*, vol. 702, nº 1, p. 63-72, 2013, https://doi.org/10.1007/s10750-012-1307-6

[55] I. Nordhaus, K. Diele, & M. Wolff, « Activity patterns, feeding and burrowing behaviour of the crab Ucides cordatus (Ucididae) in a high intertidal mangrove forest in North Brazil », *Journal of Experimental Marine Biology and Ecology*, vol. 374, nº 2, p. 104-112, juin 2009, https://doi.org/10.1016/j.jembe.2009.04.002

[56] I. Nordhaus & M. Wolff, « Feeding ecology of the mangrove crab Ucides cordatus (Ocypodidae): food choice, food quality and assimilation efficiency », *Mar Biol*, vol. 151, nº 5, p. 1665-1681, 2007, https://doi.org/10.1007/s00227-006-0597-5

[57] M. A. A. Pinheiro, M. R. Souza, L. C. M. Santos, & R. F. C. Fontes, « Density, abundance and extractive potential of the mangrove crab, *Ucides cordatus* (Linnaeus, 1763) (Brachyura, Ocypodidae): subsidies for fishery management », *An. Acad. Bras. Ciênc.*, vol. 90, nº 2, p. 1381-1395, 2018, https://doi.org/10.1590/0001-3765201820170090

[58] A. C. Wunderlich & M. A. A. Pinheiro, « Partitioning of mangrove habitat by Ucides cordatus (Ucididae): effects of tidal flooding degree and tree species composition throughout its life cycle », *Helgoland Marine Research*, vol. 64, p. 279-289, 2013.

[59] R. D. C. Conti et R. C. Nalesso, «Status of the population structure of the mangrove crab Ucides cordatus (Decapoda: Ocypodidae) on the Piraquê-açu River estuary, Espírito Santo, Brazil », *Braz. j. oceanogr.*, vol. 58, nº 2, p. 81-92, 2010, https://doi.org/10.1590/S1679-87592010000200001

[60] P. Goes, J. O. Branco, M. A. A. Pinheiro, E. Barbieri, D. Costa, & L. L. Fernandes, « Bioecology of the uçá-crab, Ucides cordatus (Linnaeus, 1763), in Vitória Bay, Espírito Santo State, Brazil », *Braz. j. oceanogr.*, vol. 58, nº 2, p. 153-163, 2010, https://doi.org/10.1590/S1679-87592010000200006

[61] C. Edmond, J. Mouton,& D. L. Felder, « Reproduction of the Fiddler Crabs *Uca longisignalis* and *Uca spinicarpa* in a Gulf of Mexico Salt Marsh », *Estuaries*, vol. 18, nº 3, p. 469-481, 1995, https://doi.org/10.2307/1352365

[62] V. M. Ngo-Massou, G. L. Essome-Koum, E. Kotte-Mapoko, & N. Din, « Biology and Distribution of Mangrove Crabs in the Wouri River Estuary, Douala, Cameroon », *JWARP*, vol. 06, nº 04, p. 236-248, 2014, https://doi.org/10.4236/jwarp.2014.64029

[63] M. Mokhtari, A. Savari, H. Rezai, P. Kochanian, & A. Bitaab, « Population ecology of fiddler crab, Uca lactea annulipes (Decapoda: Ocypodidae) in Sirik mangrove estuary, Iran », *Estuarine, Coastal and Shelf Science*, vol. 76, nº 2, p. 273-281, janv. 2008, https://doi.org/10.1016/j.ecss.2007.07.010

[64] M. W. Skov & R. G. Hartnoll, « Paradoxical selective feeding on a low-nutrient diet: why do mangrove crabs eat leaves? », *Oecologia*, vol. 131, nº 1, p. 1-7, mars 2002, https://doi.org/10.1007/s00442-001-0847-7

[65] K. Kathiresan & B. L. Bingham, « Biology of mangroves and mangrove Ecosystems », *Progress in marine biology*, vol. 40, p. 81-251, 2001, https://doi.org/10.1016/S0065-2881(01)40003-4

[66] S. Cannicci, M. Gomei, F. Dahdouh-Guebas, R. Rorandelli, & A. Terlizzi, «Influence of seasonal food abundance and quality on the feeding habits of an opportunistic feeder, the intertidal crab Pachygrapsus marmoratus », *Mar Biol*, vol. 151, nº 4, p. 1331-1342, 2007, https://doi.org/10.1007/s00227-006-0570-3

[67] L. Ibanga, J. A. Nkwoji, A. Usese, I. Onyema, & O. Chukwu, « Macrobenthic invertebrate community structure and heavy metals concentrations in the crab, Uca tangeri in a Tidal Creek, Niger delta, Nigeria ».

[68] R. O. Moruf & T. A. Ojetayo, « Biology of the West African fiddler crab, Uca tangeri (Eydoux, 1835) (Decapoda: Ocypodidae) from a mangrove wetland in Lagos, Nigeria », *International Journal of Aquatic Biology*, vol. 5, nº 4, p. 263-267, 2017, https://doi.org/10.22034/ijab.v5i4.328

[69] A. O. Numbere, « Impact of Human Disturbance on Fiddler Crab (Uca tangeri) Burrow Morphology, Distribution and Chemistry at Eagle Island, Niger Delta, Nigeria », *Open Journal of Marine Science*, vol. 10, nº 4, p. 191-202, 2020, https://doi.org/10.4236/ojms.2020.104015

[70] A. Chumsri *et al.*, « Human disturbance affects behavioural time allocation in a fiddler crab (Austruca annulipes) in Southern Thailand », *J. Anim. Behav. Biometeorol.*, vol. 11, nº 3, p. 2023025, 2023, https://doi.org/10.31893/jabb.23025

[71] P. Hatkar, K. Vachhrajani, & S. Kuppusamy, « Marine Benthic Diversity of the Gulf of Kutch, Gujarat: A review », *UPJOZ*, vol. 45, nº 15, p. 268-283, 2024, https://doi.org/10.56557/upjoz/2024/v45i154243

[72] K. Mulat & A. Mekoya, « Impact of Fine Sediment on Benthic Macro invertebrates Communities of Freshwater Ecosystem: A Review », *East Afr. j. for. agrofor.*, vol. 7, nº 1, p. 146-174, 2024, https://doi.org/10.37284/eajfa.7.1.1895

[73] L.-Uta. E. Okon *et al.*, « Faunal Assemblages and Biota-substrate Interactions in Tropical Nigerian Tidal Flats: Influence of Sediment Grain Size and Physicochemical Parameters », *AJOGER*, vol. 8, nº 2, p. 278-294, 2025, https://doi.org/10.9734/ajoger/2025/v8i2199

[74] P. Legendre & L. Legendre, *Numerical Ecology*. Elsevier, 2012.

[75] S. E. Hampton *et al.*, « Big data and the future of ecology », *Frontiers in Ecology and the Environment*, vol. 11, nº 3, p. 156-162, 2013, https://doi.org/10.1890/120103

[76] M. Apel & M. Türkay, « Taxonomic Composition, Distribution and Zooeoahic Relationships of the Grapsid and Ocypodid Crab Fauna of Intertidal Soft Bottoms in the Arabian Gulf », *Estuarine, Coastal and Shelf Science*, vol. 49, p. 131-142, 1999, https://doi.org/10.1016/S0272-7714(99)80018-3

[77] F. J. Rodríguez-Tovar, E. Mayoral,& A. Santos, « Influence of Physicochemical Parameters on Burrowing Activities of the Fiddler Crab *Uca tangeri* at the Huelva Coast (Southwest Spain): Palaeoichnological Implications », *Ichnos*, vol. 21, nº 3, p. 147-157, juill. 2014, https://doi.org/10.1080/10420940.2014.930035