Chapter

Intermediate Host Snails of Human Schistosomes in the Senegal River Delta: Spatial Distribution According to Physicochemical Parameters

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Abstract

The objective of the study was to evaluate the influence of physicochemical parameters of water on the spatial distribution of snail intermediate hosts of human schistosomes in the Senegal River Delta. Eight water points in three endemic villages for schistosomiasis were selected for biweekly monitoring of snail numbers and physicochemical parameters of water at the beginning of the rainy season. The results show that the spatial distribution of snail populations is a function of certain parameters. The pH, the dissolved oxygen and its saturation, and the temperature have a positive influence on the *Bulinus* and *Biomphalaria*, while the conductivity, the speed of flow, and the salts (phosphates, salinity, and nitrates) seem to act negatively on the populations of these snails.

Keywords: physicochemical parameters of water, snails, intermediate hosts, schistosomiasis, spatial distribution, Delta, Senegal

1. Introduction

Schistosomiasis is among the most widespread human parasitic diseases with more than 200 million people infected worldwide, with the majority of these infections occurring in sub-Saharan Africa. The human schistosomiasis species present in Senegal are *Schistosoma haematobium* and *S. mansoni* which are transmitted by contact with freshwater snails as an intermediate host and caused urinary or intestinal schistosomiasis, respectively. The intermediate host for *S. mansoni* belongs to the genus *Biomphalaria pfeifferi*, while genus *Bulinus* harbors *S. haematobium* [1–3]. *Biomphalaria pfeifferi* is the only species involved in the transmission of *S. mansoni* in Senegal [4]. It was in the late 1980s that the first cases of intestinal schistosomiasis were diagnosed in the town of Richard-Toll, north-east of the lower Senegal River valley [5]. The transformation of the environment by human agricultural activities favors the creation of breeding sites for the development of snails that spread to other sites [6, 7]. This situation has been aggravated by hydraulic developments, the construction of numerous small and large dams, as well as the multiplication of irrigation canals [8]. The modification of the practices of the populations bordering these developments is also concretized by intensification of human contact with infected water [9]. These factors contribute to the evolution of the incidence of these schistosome infections and their pathologies in the region [10].

In the present study, the importance of the physicochemical parameters of surface waters (pH, dissolved oxygen, conductivity, phosphates, salinity, nitrates, temperature, and flow velocity of water) on the spatial distribution of snail intermediate hosts of schistosomes in human beings has been studied.

2. Material and method

2.1 Study sites

The choice of prospecting sites was guided by their human and animal associations and the presence of human schistosomiasis transmission. The selected villages are bordered by creeks and tributaries of the river in which local people carry out domestic or work activities related to water (**Figure 1**).

In this study, the three villages that have been selected were co-exposed to *S. haematobium* and *S. mansoni* infection. The village of Menguègne Boye (ME) (16°017,315 N, −16°356,659 O) has four (04) water points (ME1, ME2, ME3, ME4), the village of Ndellé Boye (NE) (16°168,725 N, −16°289,124 O) has two (02) water points (NE1, NE2), and the village of Thilla (TA) (16°054,994 N, −16°331,894 O) also has two (02) water points (TA1 and TA2). NE1 and NE2 are separated by a dam and communicate with each other through transverse pipes.

The study covers the period from 03 July to 02 August 2017 (beginning of the rainy season), due to a survey every 15 days from 9 am to 12 am. Three surveys

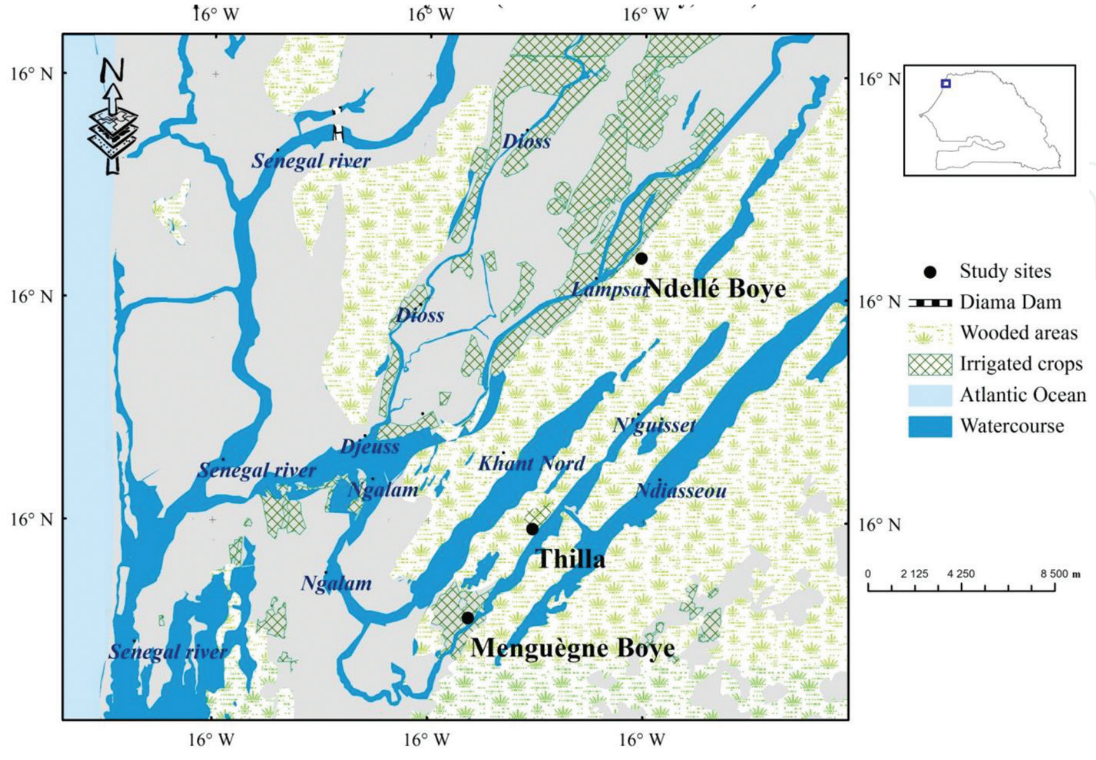

Figure 1.
Map of the study sites.

at the different water points constituting zones of human-water contact, zones of transmission of the disease, were carried out. In parallel with the malacological investigations, in situ measurements of the physicochemical factors were conducted.

2.2 Evaluation of physicochemical parameters

The evaluation of the physicochemical parameters was carried out to a depth not exceeding 0.5 meters. Conductivity (μS/cm), salinity (psu), dissolved oxygen (mg/l) and its saturation (%), and nitrate concentration (mg/l) were measured with the YSI 600 multiparameter digital probe recorder (HANNA instruments). The plunging probes were covered by a scraper. Phosphate measurement (mg/l) was performed by using the Phosphate High Range (PHR) model HI 96717 C (HANNA instruments). Briefly, 10 ml of water was first mixed in a tube with the reagent Phosphate HR Reagent B (HANNA instruments). Then the tube was placed in the device for 3 minutes to obtain the value. Hydric potential (pH) was obtained using an ESEE pH-meter (HANNA instruments) by immersion of a probe. The flow velocity (m/s) and the water temperature (°C) were measured by a flowatch (JDC electronic) equipped with a submerged propeller at a depth of 0.5 meters.

2.3 Malacological study

2.3.1 Snail collection

The presence of snails was looked for at each water point using a wire wick (2.5 mm) by diversifying the areas surveyed. The areas of prospect were the *Typha* area, floating vegetation, and mud. Depth was measured before each scoop with the dip net. The number of scoops was a function of the surface of the water point and varied between 10 and 15. After washing the vegetation in the basin, the water was filtered using a metal screen (2.5 mm) only passing water and fine debris. The snails were harvested with tongs. All snails from the same waterhole were grouped in one or more pots if necessary and brought to the laboratory for identification.

2.3.2 Identification of snails

The identification is based on the Mandahl-Barth key based on the morphology of the shell. Snails not identifiable to the eye were observed with a binocular magnifying glass. The latter method was mainly of interest to snails of the genus *Bulinus* because the species of the genus *Biomphalaria pfeifferi* is easily recognizable by the discoid shape of its shell. The density (d) of snails was expressed in (average) numbers of snails per scoop [11].

2.4 Statistical analyses

The R Studio, Excel software, and XLSTAT extension were used for the analysis of the results. Results are presented +/− SD averages. In order to establish a relationship between the different physical (conductivity, flow rate, water temperature) and chemical (dissolved oxygen, saturation, water salinity, pH, nitrate contents, and phosphates) parameters and the density of snails, a statistical principal component analysis (PCA) was applied to all variables. With XLSAT, the realization of principal component analysis allowed to analyze a table of observations/quantitative variables or a correlation or covariance matrix.

3. Results

3.1 Physicochemical parameters of the water points

The averages of the eight [8] abiotic factors measured in our eight water points are shown in **Figure 2**. The highest water temperature was observed at Mbenguègne Boye (ME3) with 29.9°C. Thilla with its first site (TA1) recorded 29.8°C, while Ndellé Boye had the lowest temperature from its second NE2 water point with 28.5°C. Only the water points NE2 and TA2 recorded a speed greater than 0 (zero) with, respectively, 1 m/s and 3 m/s. The maximum conductivity was obtained at Ndellé Boye: 200.26 µS/cm for NE1 and 195.16 µS/cm for NE2. The lowest conductivity content was found at the first Menguègne Boye point (ME1, 132.06 µS/cm). Dissolved oxygen (mg/l) showed +/− significant variations from 38.3 mg/l to ME3 to 5.7 mg/l to TA2. At Menguègne Boye the maximum dissolved O_2 content was observed at ME1

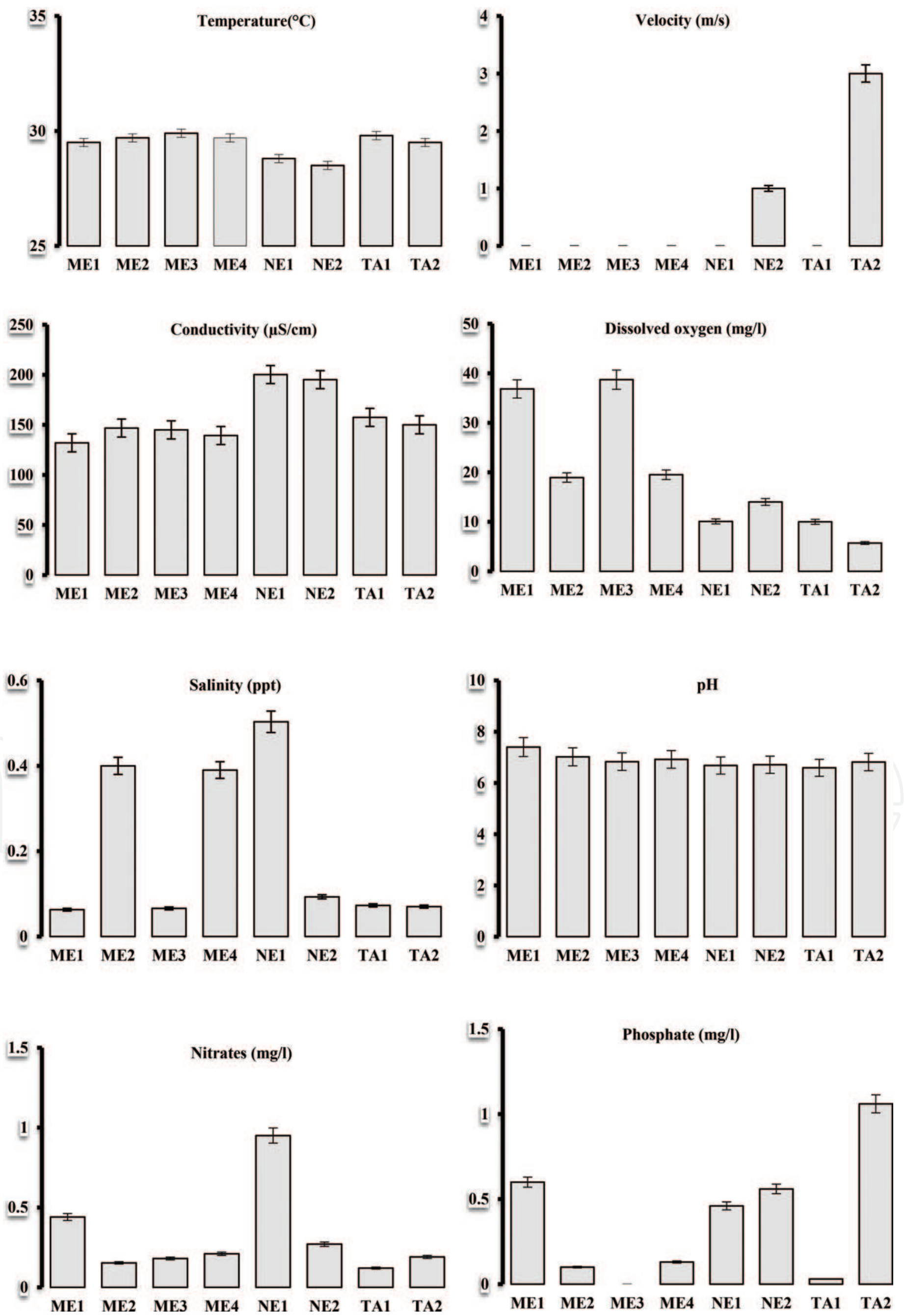

Figure 2.
Physicochemical data (average) of the water points.

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Site	Water point	Biom.	B. fors.	B. glob.	B. sene.	B. trun.
Menguègne Boye	**ME1**	2.16 (± 0.64)	1.04 (± 0.31)	0.5 (± 0.15)	0.11 (± 0.03)	27.54 (± 8.26)
	ME2	0.3 (± 0.09)	1.1 (± 0.33)	0.46 (± 0.13)	0.93 (± 0.27)	4.43 (± 1.32)
	ME3	0	0	0,13 (± 0,04)	0	2,86 (± 0,85)
	ME4	0.06 (± 0.01)	0.2 (± 0.06)	0.13 (± 0.041)	0	1.26 (± 0.37)
Ndellé Boye	**NE1**	0	0	0	0	0,69 (± 0,20)
	NE2	0	0.47 (± 0.14)	0	0.38 (± 0.11)	5.32 (± 1.59)
Thilla	**TA1**	2.38 (± 0.71)	0.05 (± 0.01)	0.076 (± 0.02)	0	1.38 (± 0.41)
	TA2	0	0.06 (± 0.01)	0	0	0.06 (± 0.01)

Biom. = Biomphalaria, B. = Bulinus, fors. = forskalii, glob. = globosus, sene. = senegalensis, trun. = truncatus.
***ME**= Mbenguègne Boye, **NE**= Ndellé Boye, **TA**= Thilla*

Table 1.
Density of intermediate host snail of human schistosomes (number of molluscs/scoop).

36.83 mg/l and ME3 (38.7 mg/l). Thilla had the lowest dissolved O_2 content at point 2 (5.7 mg/l at TA2). The salt content obtained is very weak (1 ppt = 1–9 mg/l). We found in Ndellé (NE1) the largest salt measure (0.503 psu), followed by ME2 with 0.4 ppt. The lowest levels were found at ME1 (0.063 psu) and ME3 (0.066 psu). The pH showed its maximum values in Menguègne Boye—7.4 to ME1, 7.02 to ME2, and 6.92 at ME4—while Thilla recorded the lowest value at its first point (6.59). At Ndellé, we had the maximum nitrate content (0.95 mg/l) and the average phosphate levels: 0.46 mg/l at point 1 (NE1) and 0.56 mg/l at NE2. TA2 had the highest phosphate content (1.06 mg/l), and TA1 showed only 0.03 mg/l, while we found 0 mg/l at the third point of Menguégne Boye.

3.2 Malacological data

The malacofauna intermediate host of human schistosomiasis consisted of *Biomphalaria pfeifferi*, *Bulinus forskalii*, *B. globosus*, *B. senegalensis*, and *B. truncatus*. The total population of snails recovered in the three villages (eight water points) was 2068 snails. The analysis of the malacological data showed that *B. truncatus* colonized all study sites (**Table 1**). Its dominance within this stand was observed in all water points. However, ME1 had the highest density of *B. truncatus*, while *B. globosus* (0.5 individuals/scoop) is absent at Ndellé (NE1, NE2) and TA1. *B. forskalii* was mainly present in Menguègne Boye with d = 1.04 at ME1 and d = 1.1 at ME2. *B. senegalensis* was found only at Mbenguègne Boye (ME1 and ME2) and at the second point of Ndellé (NE2, d = 0.38). *Biomphalaria pfeifferi* was the second most represented species (d = 2.16 at ME1 and d = 2.38 at TA1) after *B. truncatus*.

3.3 Relationship between intermediate hosts snails of schistosomes and measured abiotic factors of the biotope

Figure 3 shows that the presence of intermediate snail hosts was positively correlated with temperature, pH and dissolved oxygen, and its saturation. Salts (phosphate, salinity, and nitrates), conductivity, and velocity did not have any direct effect on the presence of snails. The PCA indicates that the pH, the dissolved O_2, and its saturation (%) were strongly linked to the presence of the species *B. globosus, B. truncatus*, and *B. forskalii*, whereas they were moderately related to that of *Biomphalaria* as shown in the correlation matrix. Projections on PCA of salinity, nitrate, and phosphate levels of water are orthogonal to those of snails in general, indicating that there were no significant direct influences of these

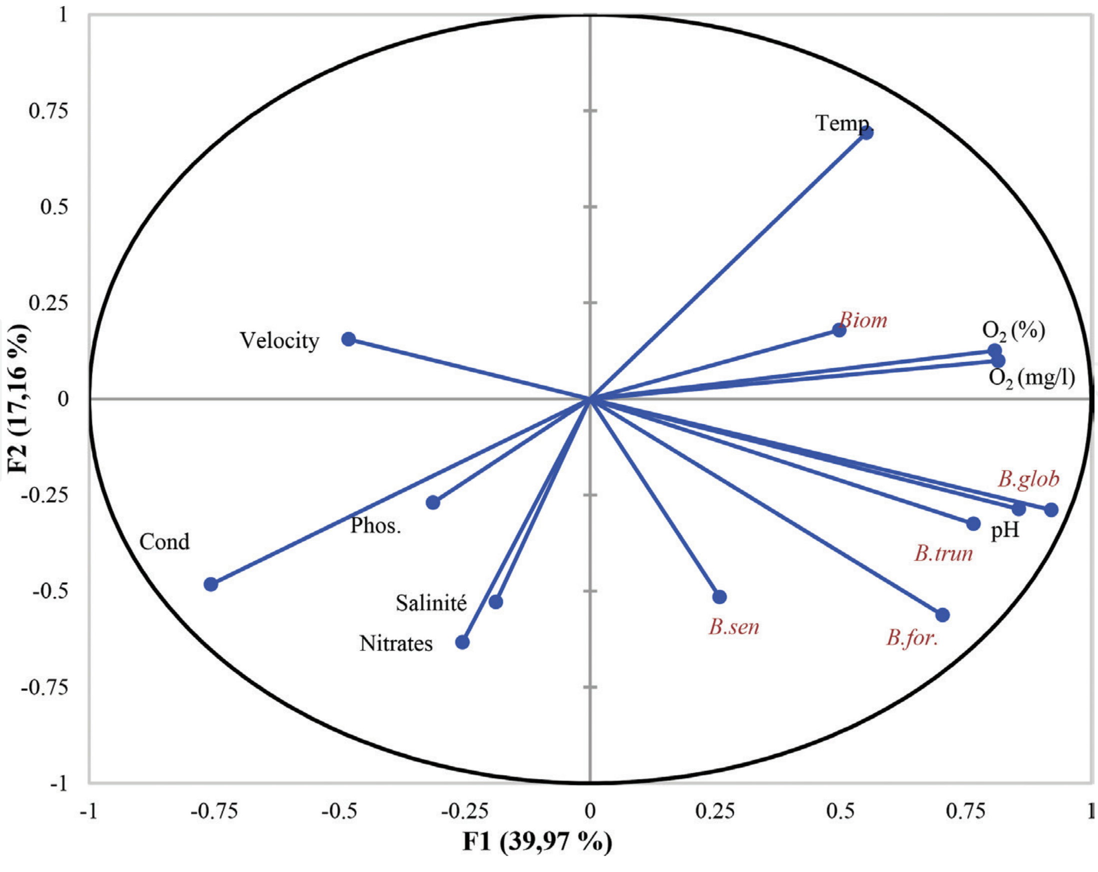

Figure 3.
Relationship between the density of intermediate host snails and the physicochemical parameters of water.

parameters on snail populations. The temperature is positively correlated with *Biomphalaria*. Conductivity, velocity, and salinity are more or less opposed to those of *B. globosus, B. truncatus*, and *B. forskalii*.

4. Discussion

The temperatures measured ranged from a minimum of 28.5°C to Ndellé Boye to a maximum of 29.9°C to ME3. The lowest temperatures recorded at Ndellé could be explained by the fact that the freshwater ecosystem found in this environment is less exposed to light because of its highly developed eutrophication. It has been shown [11] that during the month of July, water temperatures on the other side of the Senegal River (Right River) vary between 26.1°C and 28.9°C. pH values vary almost by one unit (between 6.59 and 7.4). Its slight basicity accompanies the words of N'Diaye *et al*. [12] who said that the pH values measured in the waters of the Senegal River place the latter in the excellent to good level of surface water (6.5 < pH < 8.5). Phosphate and nitrate contents would not only come from agricultural land (leaching of fertilizers by rainwater) but also from household activities for which women use different detergents and antiseptics. Halstead et al. [13] shows the potential impact of agrochemicals on the transmission of schistosomiasis and therefore on snails. In a recent study in the same region, Diallo et al. [14] argue that washing clothes directly in the river alone probably justifies the presence of phosphates. They also argue that rains can be an important vector for the transport of domestic waste, urine, and excrement of animals to the river by the phenomenon of leaching. The strong eutrophication noted on the biotope particularly to Ndellé Boye would come from the important contents of nitrates and phosphates in the water. In addition, the presence of the Diama Dam and the association of dikes reduce the oxidation and flow velocity of the valley water [15]. These facts, combined with waste dumps around the villages and cities and agrochemicals from irrigated fields, accelerated eutrophication of water in the Senegal River Valley. The very low salt levels indicate that the watercourses of our study sites are freshwater ecosystems. The electrical conductivity which is a measure of the ability of an aqueous solution to conduct electrical current shows significant variations (132.06 and 200.26 μS/cm). The high levels obtained to Ndellé (200, 26 μS/cm at NE1 and 195.16 μS/cm to NE2) are due to the strong contributions of organic matter in the water, resulting in their greater mineralization. By comparing the values of the conductivity measured at the WHO reference water level, which is 300 μs/cm [16], we deduce that the water from these effluents of the Senegal River is of good quality. However, a study by Tfeila et al. [17] on the Senegal River indicates a much smaller variation (47.4 and 67.1 μS/cm) than that observed in our study sites.

The simultaneous presence of both intermediate host snail species is indicative of the existence of both schistosomiases in the study area. Diaw et al. [18] note the presence of *Biomphalaria pfeifferi, Bulinus globosus, B. truncatus, B. senegalensis*, and *B. forskalii* at Mbodiène bordered by Lampsar, which was a major focus of schistosomiasis. It also shows the existence of these organisms in the delta with an increase in populations of *Biomphalaria* and a wider distribution. Five [5] species of snail intermediate hosts of human schistosomes in Senegal were found in our study sites. *B. senegalensis*, an intermediate host of *S. haematobium*, is very common and abundant in the regions of Saint-Louis, Tambacounda, Kaolack, and Fatick [19, 20]. We thus find its presence in Menguègne Boye (d = 0.11 for ME1 and 0.93 for ME2). *B. globosus* and *B. truncatus*, intermediate hosts of *S. haematobium*, are very commonly found in the Senegal River delta. *Biomphalaria pfeifferi*, the main intermediate host of *S. mansoni*, was not found in Ndellé Boye although its presence has been previously mentioned [21] in Lampsar. These authors indicate that in the delta, this species was the most abundant in the early 1990s. However, the presence of this snail in Thilla and Menguègne Boye with respective densities of 2.38 and 2.16 was quite poor, which has been confirmed by the work of Ndir [20] who supports a reduced presence in the delta but with a range tending to extend toward the southern region (Louga region) since the impoundment of the dams. The dominance of *B. truncatus* in our study sites is very remarkable. This could be explained by the fact that the sites Menguègne Boye, Ndellé Boye, and Thilla are permanent watercourses. Gbocho et al. [16] confirm that they are favorable to the proliferation of this species.

The presence of biotopes favorable or not to the life of the snails is due to ecological transformations of the environments. Among these transformations, we can note the presence of vegetation that could determine the presence or absence of snails [22]. The physicochemical conditions that accompanied ecological changes could influence the distribution of snails. A high rate of water conduction has been noted at TA2; the rarity of snails observed at this point of water could be due to speed. Speed is a physical factor that opposes the residence of snails if it exceeds 0.3 m/s [19]. The values obtained for oxygen and pH are favorable for the habitat of gastropods. The study shows a positive correlation between temperature and *Biomphalaria*, whereas temperatures of 29.9°C have no influence on the *Bulinus*. In a study done in the lake of the Taabo Dam in Côte d'Ivoire, Gbocho et al. [16] show a positive correlation of temperature with *Biomphalaria* at a maximum T° of 31.5°, whereas this temperature acts negatively on the populations of *Bulinus*. The measured salinity has no significant influence on snails (except *Biomphalaria* and *B. truncatus* species). This could be due to its very low content. Diaw et al. [19] give the example of the effects of this parameter on the development of snails in the delta of the Senegal River where these gastropods have proliferated after the start of operation of the Diama anti-salt dam. Significant values of conductivity obtained at Ndellé

(200, 26 µS/cm at NE1 and 195.16 µS/cm to NE2) generally have a negative effect on the density of snails. Which could confirm the remarks of Gbocho et al. [16] who argue that conductivity levels (74 and 77.4 µS/cm) that they observed do not correlate significantly with intermediate host populations because of its low values. Our study demonstrates that physicochemical parameters such as conductivity, dissolved oxygen and its saturation, pH, and water flow velocity have an important role on the spatial distribution of snail intermediate hosts of human schistosomiasis.

5. Conclusion

The study of the influence of physicochemical parameters on the spatial distribution of intermediate snail hosts in human schistosomes in the Senegal River delta provided insights on the diversity of snail and their density and, secondly, the role of these parameters in the distribution of snails. The presence of snail intermediate hosts of human schistosomes would be conditioned by the temperature, oxygen, and pH with which they are positively correlated. An increase in salt (phosphates, nitrates, and salinity), conductivity, and velocity would lead to a lower density of snails.

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