parasitologia

Low Malaria Transmission in Rosso, an Irrigated Rice-Growing Area in Mauritania

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Abstract: The construction of dams along the Senegal River resulted in an increase in irrigated land areas and changes in the epidemiology and transmission of water-related diseases. The objective of this study was to update epidemiological data on malaria in Rosso, one of the major Mauritanian cities along the Senegal River. Febrile patients (n = 318) were screened for malaria using a rapid diagnostic test (RDT) for malaria and microscopic examination of blood smears. Diagnosis was later confirmed by polymerase chain reaction (PCR). The mean age of 318 febrile patients was 25.1 (range 1–80 years). Only 7 (2.2%) and 2 (0.6%) had a positive RDT and thick smear, respectively. PCR confirmed the diagnosis in two *Plasmodium vivax*-infected patients. Most participants (198/318, 62.3%) had no recent travel history outside Rosso. The majority of the febrile patients (90%, 284/311) owned at least one insecticide-treated net (ITN). The frequency of the use of ITNs was not significantly associated with season (rainy vs. dry seasons; p = 0.9) or with the number of ITNs per household (r_s = 0.07; n = 285; p = 0.19). Of 285 individuals with ITNs, only two (0.7%) with no travel history were PCR-positive for malaria. Despite the presence of mosquito breeding sites related to rice irrigation, malaria transmission in Rosso remained very low, possibly due to the high coverage and frequent use of bed nets. Regular entomological surveillance for possible changes in the prevalence of *Anopheles* mosquito species and their behavioural aspects should be implemented.

Keywords: *Anopheles arabiensis*; dam; drug resistance; insecticide treated nets; *Plasmodium vivax*; *Plasmodium falciparum*; rice cultivation

1. Introduction

Malaria is a life-threatening disease caused by the parasites of the genus *Plasmodium*. In 2019, an estimated 229 million malaria cases and 409,000 deaths due to malaria were reported globally [1]. Sub-Saharan Africa accounted for 94% of malaria cases [1]. The malaria parasite is transmitted to a human host by the bite of an infected female mosquito of the genus *Anopheles* during a blood meal. The feeding pattern of female *Anopheles* mosquito depends largely on host availability and preference. Female *Anopheles* mosquitoes that feed

preferentially on human blood (i.e., anthropophilic) are more competent in transmitting human malaria than those that prefer to feed on animal blood (i.e., zoophilic).

In Mauritania, malaria is endemic throughout the country with two main patterns of transmission, depending on the climatic and geographic conditions: (i) a generally low and sporadic (or seasonal) transmission in the northern Saharan zone with *Plasmodium vivax* as the main causative parasite species and (ii) a low to high seasonal transmission, with some hotspots, in the southern Sahelian zone where *P. falciparum* predominates [2–6]. In these two malaria transmission areas of the country, malaria mostly occurs during and shortly after the wet season (July–November) with a peak in October shortly after the end of the rainy season. *Anopheles arabiensis* is the main malaria vector in Mauritania [7–9].

The use of bed nets is one of the measures to prevent malaria. It is now established that insecticide-treated nets (ITNs) are effective in reducing malaria morbidity when used consistently [10]. Moreover, in rural areas, studies have shown that individuals often make better use of insecticide-treated or untreated bed nets as a protective measure against mosquito bites than those living in urban or semiurban areas [11]. In this context, the field evaluation of the use of bed nets by the population is important to assess their efficacy to control malaria.

Irrigation schemes have been developed in the Senegal River valley, a natural border between Mauritania and Senegal, with the principal aim to support and improve rice production [12–14]. Rice fields are known to be a favourable habitat for *Anopheles gambiae* sensu lato (s.l) larvae, the major malaria vector in sub-Saharan Africa [15] In Mauritania, the construction of dams along the Senegal River resulted in an increase in irrigated land areas, mainly for rice (*Oryza sativa* L.) cultivation, and changes in the epidemiology and transmission of water-related, vector-borne diseases, such as malaria, schistosomiasis, and filariasis [7,16]. For instance, prior to the construction of the Diama dam located about 22 km upstream from the Atlantic Ocean in 1986, epidemiological data from the Senegalese side of the Senegal River showed that malaria was the most frequently encountered water-related disease in the medical records of the majority of districts along the river [16–20]. However, studies conducted in the same zone several years later showed an extremely low seasonal malaria transmission despite the establishment of primary and secondary vectors of malaria, *An. arabiensis, An. gambiae* sensu stricto (s.s), and *An. pharoensis* [7,21,22]. In general, *An. arabiensis* is both anthropophilic and zoophilic, and *An. gambiae* s.s is more anthropophilic than zoophilic. On the right bank (i.e., the Mauritanian side) of the Senegal River, malaria surveillance has not been performed regularly along the river valley. The objective of this study was to update epidemiological data on malaria in Rosso, one of the major Mauritanian cities situated along the Senegal River where a permanent irrigation scheme has been established for decades [12]. Our results suggest that the level of malaria transmission remains very low in Rosso.

2. Results

2.1. Demographic Characteristics of Patients

Overall, 318 febrile patients (*n* = 246 [77.4%] in 2015; *n* = 72 [22.6%] in 2016), comprising 227 (71.4%) and 91 (28.6%) individuals belonging to the Moorish and black African ethnic groups, respectively, were screened for malaria (Table 1). The mean (range) and median ages of the participants were 25.1 years (1–80 years) and 22.5 years, respectively. Of 318 febrile patients recruited, 115 (36.2%) were between 20 and 39 years old, and 30 (9.4%) were children less than 5 years old. A total of 153 (48.1%) patients were males, with a male-to-female ratio of 0.93. Most of the patients (198/318, 62.3%) had no recent (i.e., less than 6 months before consultation) travel history outside Rosso.

2.2. Clinical Presentation and Malaria Diagnosis

The mean (range) axillary temperature of the patients at the time of consultation was 38.0 °C (35.3–40.5 °C), and the mean (range) haemoglobin was 10.5 g/dL (6.0–13.0 g/dL) (Table 1). Symptoms suggestive of malaria were reported by 311 of 318 (97.8%) febrile

patients. Headache, fever, and loss of appetite were the most common symptoms with 304 (97.7%), 147 (47.2%), and 118 (37.9%) cases, respectively. However, most symptoms, including fever, are not specific to malaria.

Seven (2.2%) patients were positive for malaria by RDT (five *P. falciparum* and two non-*falciparum*), four in 2015 and three in 2016. RDT-positive patients included two young children, both aged 4 years old, one older child (16 years old), and adults (35–45 years old). Five RDT-positive cases occurred during the rainy season (three in 2015 and two in 2016), whereas two were RDT-positive during the dry season (1 in 2015 and 1 in 2016). Four of these RDT-positive patients travelled recently to Nouakchott (*n* = 3) or the Assaba region situated in southern Sahelian Mauritania (*n* = 1), where malaria transmission is known to occur throughout the year (in Nouakchott) or is seasonal (in Assaba region). Of these seven patients with positive RDT results, two (0.63%) were smear-positive (both *P. falciparum*; parasitaemia < 1800 asexual parasites/μL of blood). The discordant results between RDT and microscopy were most probably due to low parasitaemia.

Diagnostic PCR was performed to detect *P. falciparum*, *P. vivax*, *P. ovale*, and/or *P. malariae*. PCR confirmed that two of the seven RDT-positive cases were due to *P. vivax*. One PCR-confirmed *P. vivax* infection was observed in a 16 year-old girl who had a recent travel history to Nouakchott during the rainy season in 2015. Data on bed net use during her stay in Nouakchott were not available. The second case of PCR-confirmed *P. vivax* infection occurred in a 35 year-old man, without any recent travel history outside Rosso, who claimed to 'always' sleep under the bed net. The other five RDT-positive cases were false positives, probably due to previous malaria infections (with residual circulating malaria parasite antigens detected by RDT).

Table 1. Baseline characteristics of the study population.

Characteristics	2015	2016	2015–2016
Number (%)	246 (77.4)	72 (22.6)	318 (100)
Sex (n, %)			
Male	119 (48.4)	34 (47.2)	153 (48.1)
Female	127 (51.6)	38 (52.8)	165 (51.9)
Age group (year; n, %)			
<5	23 (9.3)	7 (9.7)	30 (9.4)
5–9	35 (14.2)	15 (20.8)	50 (15.7)
10–19	42 (17.1)	14 (19.4)	56 (17.6)
20–39	95 (38.6)	20 (27.7)	115 (36.2)
40–59	38 (15.4)	9 (12.5)	47 (14.8)
≥60	13 (5.3)	7 (9.7)	20 (6.3)
Mean axillary temperature (°C) (range)	37.9 (35.3–40.5)	38.0 (36.0–40.0)	38.0 (35.3–40.5)
Mean haemoglobin (g/dL) (range)	10.1 (6.0–13.0)	11.0 (8.4–12.0)	10.5 (6.0–13.0)
Ethnicity			
Moors	179 (72.8)	48 (66.7)	227 (71.4)
Black Africans	67 (27.2)	24 (33.3)	91 (28.6)
Travel history			
Yes	106 (43.0)	14 (19.5)	120 (37.7)
No	140 (57.0)	58 (80.5)	198 (62.3)
Malaria test positivity			
Rapid diagnostic test	4 (2 Pf + 2 Pan)	3 (Pf)	7 (2.2)
Microscopy	1 (Pf)	1 (Pf)	2 (0.6)
Polymerase chain reaction	1 (Pv)	1 (Pv)	2 (0.6)

n: number; Pf: *Plasmodium falciparum*; Pv: *Plasmodium vivax*; Pan: any other *Plasmodium* species.

2.3. Ownership and Use of ITNs

Data on ITNs ownership were obtained from 311 of 318 (97.8 %) participants (Table 2; seven missing data). Of 311 respondents, 285 (91.6%) reported to own at least one ITN in their household, with a mean (range) of 3 (1–10) ITNs per household. Twenty-six patients (8.4%) reported that they did not possess any bed net. There was no statistically significant association between the number of ITNs per household and their frequency of use ($r_s = 0.076$; $p = 0.19$).

Table 2. Ownership of insecticide-treated nets among febrile patients in Rosso, southwestern Mauritania.

Characteristics	2015	2016	2015–2016
Household ownership of ITNs (n, %) [1]			
Yes	223 (91.1)	62 (93.9)	285 (91.6)
No	22 (8.9)	4 (6.1)	26 (8.4)
Number of ITNs per household (n, %)			
1	42 (18.8)	8 (12.9)	50 (17.5)
2–4	130 (58.3)	41 (66.1)	171 (60.0)
>4	51 (22.8)	13 (20.9)	64 (22.4)

[1] There were 7 missing data. Insecticide treated nets: ITN.

Figure 1 summarises the frequency and seasonality of use of ITNs among 285 participants during two consecutive dry and two consecutive wet seasons of 2015 and 2016. Although the pooled number of respondents during the dry seasons of 2015 and 2016 ($n = 167$; 58.6%) was significantly higher ($\chi^2 = 8.16$, df = 1, $p = 0.004$) compared to that of the wet seasons of the same period ($n = 118$; 41.4%), there was no significant difference ($p > 0.05$) in the use of ITNs as a protective means against mosquito bites between dry and wet seasons.
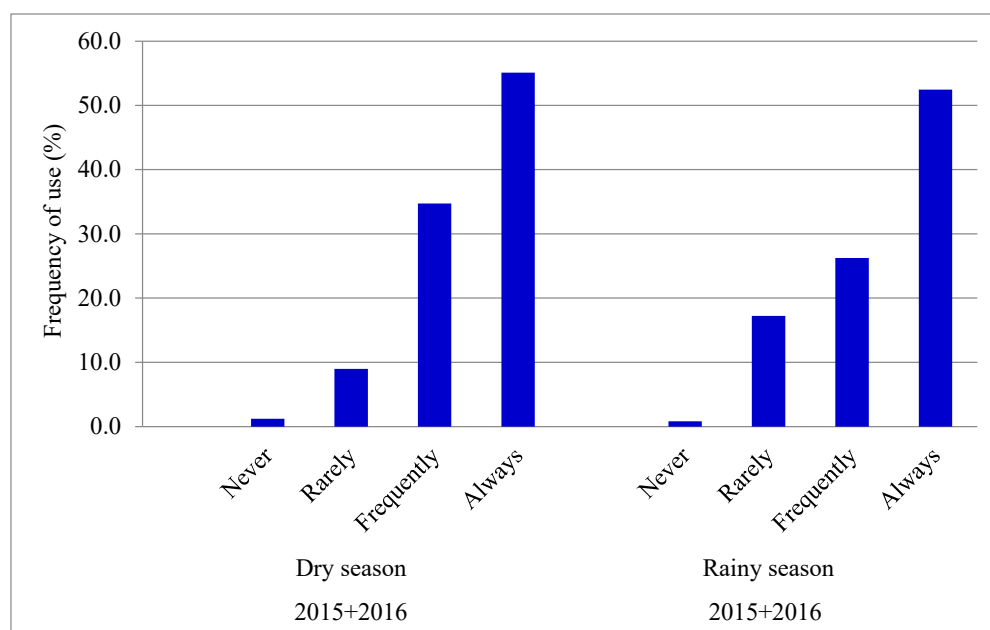

Figure 1. Seasonality and frequency of use of insecticide-treated nets among febrile patients recruited at the health centre of Rosso, southwestern Mauritania. The frequency of use of ITNs reported by the patients: "rarely" denotes less than once a month; "frequently" means at least once a week; and "always" means sleeping under ITN every night. "Dry season" refers to October to June; "rainy season" in Rosso refers to July to September. The longitudinal study was conducted for 2 complete years (2015–2016).

During the dry season, the proportion of participants who reported to have always slept under ITNs (55.1%; *n* = 92) was not statistically different from those who always slept under ITNs (52.5%; *n* = 64) during the wet season (χ^2 = 0.102, df = 1, *p* = 0.74). Similar trends in the seasonality of use of ITNs were observed in the groups of participants who frequently (34.7%, *n* = 58 vs. 26.2%, *n* = 32; *p* = 0.41), rarely (*p* = 0.48), or never (*p* = 0.97) slept under an ITN during the dry vs. wet season.

3. Discussion

The main findings of the present longitudinal study were that (i) malaria prevalence in Rosso is very low (2.2% based on RDT; 0.6% based on PCR) and (ii) high rates of mosquito net ownership and coverage (i.e., the number of ITNs per household) at the household level and high frequency of 'regular' use were observed among the study population with no variation in the seasonality of ITNs use (dry vs. wet season). Although the development and operation of water projects in this area resulted in the creation of new and highly productive mosquito larval habitats [23], these findings suggest that environmental changes had little impact on malaria transmission in Rosso.

Our results corroborate previous entomological and parasitological studies from both the left and right banks of the Senegal River where low malaria transmission had been observed in many Senegalese villages as well as in Mauritanian cities [7,18–22]. Similar findings were also reported from the villages near the city of Niono in Mali, where irrigation water is drawn from the Niger River [24]. In that Malian study, it was observed that in the irrigated zone, malaria transmission remained low throughout the year despite high densities of mosquitoes characterised by low anthropophily, while in the nonirrigated zone, malaria transmission was close to zero during the dry season and high just after the rainy season despite lower mosquito densities.

The only previously published survey of malaria epidemiology in Rosso, conducted in 2004–2006, reported comparable malaria prevalence between adult febrile patients (2.5%) consulting at the regional hospital of Rosso and asymptomatic school children aged 6–14 years (0.9%) living in two villages near Rosso, suggesting low exposure to infective mosquito bites of the population living in this area [2]. In a series of cross-sectional studies conducted in 2011–2013 in towns and villages situated along the Senegal River (namely Keur macene (situated about 84 km downstream from Rosso), Boghé (about 200 km upstream from Rosso), and Gouraye and Ghabou further upstream near Mali–Mauritanian border), only 14 of 1056 (1.3%) asymptomatic children aged 2–6 years had smear-positive malaria (eight *P. falciparum*, five *P. ovale*, and one *P. malariae*) during (i.e., October) and just after the rainy season (i.e., December) [3]. Furthermore, two studies conducted in Kaédi, a city located about 430 km upstream from Rosso, also reported a very low malaria prevalence (15/9313 positive blood smears in 4 young children <5 years old and 11 older children and adults; 13 *P. falciparum* and 2 *P. malariae*; 0.9%) in a household survey conducted during dry and wet seasons in 2014–2015 [25], and the absence of malaria parasitaemia (microscopy and lactate dehydrogenase (LDH)-based RDT) among 371 asymptomatic children aged 6–59 months recruited from a random selection of households in 2011 [26]. All of these previous cross-sectional studies along the Senegal River valley were performed during a short period of time and were based on microscopy and/or RDT to establish malaria diagnosis, without PCR to confirm the diagnosis [2,3,25,26]. These earlier studies have also shown that parasitaemia in asymptomatic carriers and symptomatic patients along the Senegal River valley are generally low (i.e., <2000 asexual parasites/µL). This observation probably explains, at least in part, the discrepancy in results seen among RDT, microscopy, and PCR in the present study, highlighting the need for a next-generation ultrasensitive RDT and/or PCR confirmation in areas where malaria prevalence is low or in areas that are in the pre-elimination phase [27–30].

Studies from East and West Africa showed that, despite high densities of *Anopheles* mosquitoes resulting from the development of hydroagricultural projects, the impact of rice farming and irrigation systems on malaria prevalence is highly variable. For instance,

studies carried out in Madagascar [31], Kenya [32], and Ethiopia [33] suggested that irrigation enhances malaria transmission. By contrast, in Mali [24], Senegal [7], and Côte d'Ivoire [34], it was found that higher densities of *Anopheles* mosquitoes in rice-growing area have no influence on the level of malaria transmission. This observation may be related to the level of acquired immunity in local human populations. The development of irrigation systems may lead to increased malaria prevalence in areas of unstable transmission because people living in these areas, such as the African highlands and desert fringes, usually have little or no immunity to malaria parasites. However, in areas where malaria transmission is stable and intense, as in most of sub-Saharan Africa, the introduction of crop irrigation was found to have little impact on malaria transmission [14].

The Diama dam, located about 40 km upstream from Saint-Louis spanning the border of Mauritania and Senegal, was one of the largest hydroagricultural projects on the Senegal River during the 1980s. It was built with the aim of stopping the inflow of saline water during the dry season and permitting the development of irrigated agriculture along the river valley. Irrigation schemes, mainly in the form of rice cultivation, have been developed since that time on both banks of the Senegal River, including areas surrounding Rosso, contributing to increased food production and economic growth.

Rosso is located in one of the eight provinces of the Sahelian southern part of Mauritania where malaria is endemic. The present longitudinal study, conducted continuously over two years, is the first to investigate ITNs coverage and usage in Rosso. Although it showed an adequate coverage of ITNs in the households in Rosso (i.e., an average of three ITNs per household), the results of the present study revealed high frequency of regular ITN usage among the participants, regardless of the season (86% of the enrolled patients slept at least frequently under an ITN). Thus, by sleeping regularly under a bed net, residents in Rosso tend to receive fewer numbers of mosquito bites and therefore have a lower chance of being infected by malaria parasites.

There is strong evidence that regular use of an ITN or a long-lasting insecticide-treated net (LLIN) substantially lowers the risks of malaria at the individual level [35,36]. Moreover, it has been reported that the introduction and prolonged usage of ITNs in a given malaria transmission area are often accompanied by a decrease in the human blood index of anthropophilic malaria vector as a result of the reduction in the number of humans as potential hosts [37]. The repellent effect of ITNs or insecticide residual spraying (IRS) is also known to decrease the human blood index of malaria vector [38]. For example, it has been reported that *An. gambiae* and *An. arabiensis*, which are the predominant malaria vectors in the irrigated areas of Podor city in Senegal located along the Senegal River (about 215 km east from Saint-Louis and roughly halfway between Rosso and Boghé) are particularly aggressive, but their anthropophilic index remained low due to the widespread use of bed nets among the villagers in the region [17]. In the case of Rosso, recent entomological studies reported the presence of *An. arabiensis* and *An. pharoensis* mosquitoes throughout the year, with mean densities of 3.6 and 1.5 indoor resting females per room, respectively [23]. Resting indoor female *An. arabiensis* mosquitoes captured in Rosso were mostly zoophilic, rather than anthropophilic, with a very low human blood index (HBI, which represents the proportion of blood-fed mosquitoes on humans) of 5.6% [23]. Therefore, the reduction in the number of available human hosts in Rosso due to the high frequency of use of ITNs seems to have resulted in a behavioural adaptation of *An. arabiensis*, which readily switched to other hosts, such as cattle and donkey, as alternative sources of blood meals [23]. Another factor that could explain the low level of malaria transmission in Rosso could be that high densities of mosquitoes that generally characterise irrigated fields reduce the longevity of infected mosquitoes such that malaria parasites do not have the time to complete their sporogonic cycle in infected mosquitoes, thus affecting the mosquitoes' capacity to transmit malaria parasite [39,40].

This is the first longitudinal malaria survey conducted over the period of two years in Rosso. Despite continuous monitoring of febrile, symptomatic patients of all ages consulting spontaneously at the public health centre, relatively few febrile patients were

seen during the study period. This observation is in sharp contrast to the malaria situation investigated simultaneously by the same research group in a Sahelian city of Kobeni, situated inland about 20 km from the Mali–Mauritanian border [6], as well as in many other Saharo-Sahelian cities in Mauritania, including Aïoun, Kankossa, Kiffa, Nbeika, Tamcheket, Timbédra, and Tintane [3,4,41]. In these Sahelian cities and towns, *P. falciparum* predominates, as in Rosso. However, malaria transmission is markedly seasonal, and in Kobeni, it affects more than half of the febrile patients consulting spontaneously at the health centre [6]. Contrary to *An. arabiensis* in Rosso, the mosquitoes are highly anthropophilic in Kobeni [23]. These contrasting features between the inland Sahelian zone and the Sahelian zone along the Senegal River valley call for different malaria interventions in these areas.

Although there is only one previous study involving symptomatic, febrile patients enrolled at the hospital in Rosso [2], all available data obtained from cities and villages situated along the Senegal River on both Senegalese and Mauritanian banks, including the present longitudinal study conducted in Rosso in 2015–2016, suggest a low prevalence of malaria along the river valley. There is strong evidence that, at least in Rosso, this observation may be associated with the behaviour of both the inhabitants who, in their majority, regularly sleep under ITNs, and *Anopheles* mosquitoes that are more zoophilic than anthropophilic. This situation is also partly due to the implementation of integrative regional development project among the riparian countries of the Senegal river basin (i.e., Guinea, Mali, Mauritania, and Senegal) over the past two decades, which made ITNs widely available to the population living in the basin, including residents in Rosso. For instance, a 2006–2013 Senegal River basin multipurpose water resources development project funded by the World Bank reported that by 2013, two years before the present study, about 84% of children under 5 years old living in the project areas along the Senegal River slept under a LLIN and that more than 2.6 million nets have been distributed during the project [42]. The malaria situation in Rosso, as well as that in several cities and villages along the Senegal River, seems to be under control and, with more aggressive interventions, be amenable to malaria elimination along the river valley. In this context, novel point-of-care malaria diagnostic technologies under development may play a role in the near future [43–47].

4. Materials and Methods

4.1. Study Area

The study was carried out in Rosso (latitude 16°34′ N; longitude 15°48′ W), one of the major cities of Mauritania (203 km south of Nouakchott, the capital of Mauritania) and the regional capital of Trarza, situated on the Senegal River, a natural frontier between Mauritania and Senegal (Figure 2). Rosso is the main gateway for passengers between Senegal and Mauritania. According to the latest available national census data in 2013, the city of Rosso comprises 33,581 inhabitants, of whom 49.4% are females, 51% are under 21 years of age, 17.1% (among people over 6 years old) are illiterate, and 58.5% are of working age (15–64 years) [48].

The climate in Rosso is typical of the Sahel, with a rainy season characterised by heavy rains lasting about 3–4 months (June/July to September/October), a relatively cool dry season (November to March), and hot dry season from April to May/June. The annual rainfall during the study period in Rosso was 354 and 216 mm in 2015 and 2016, respectively. The mean relative humidity during the same period was 65% and 62%, respectively, and the average temperature was 29 °C. Irrigated culture, almost exclusively consisting of rice, is the main agricultural activity along the Senegal River valley, including Rosso, with cultivated surface areas reaching 41,000 hectares producing 114,000 tons of rice in 2014 [49]. Besides rice, cultivation of vegetables and livestock rearing are other major agricultural activities of the population living in Rosso and along the Senegal River valley. The health structures in Rosso consisted of one public health centre and one regional hospital during

the study period. In 2015, there were a total of 26,487 medical consultations at the two main health structures of the city, including 1540 (5.8%) cases of hospitalisation [48].
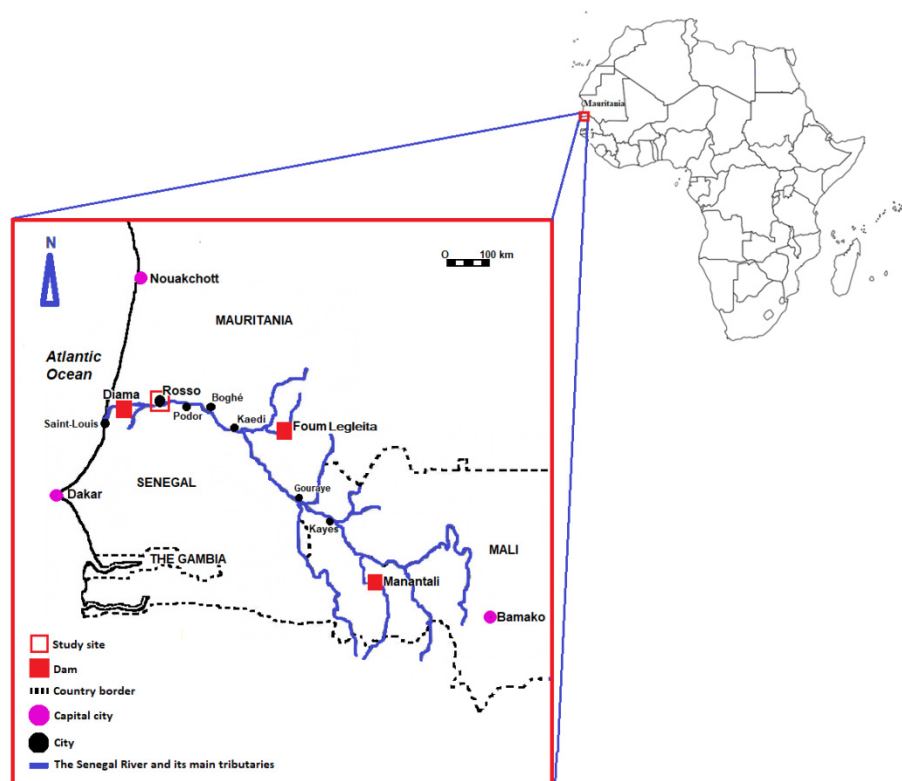

Figure 2. Map of southern Mauritania showing the geographical location of Rosso along the Senegal River, a natural frontier between Senegal and Mauritania (Sahelian zone). About two-thirds of the country's territory is desert (Sahara) or semidesert. The inset map of Africa shows the study area.

4.2. Study Population, Inclusion Criteria, and Data Collection

The present longitudinal study was conducted in the health centre of Rosso from February 2015 to December 2016. Patients of all ages with fever (defined as a measured axillary temperature $\geq 37.5\ ^\circ C$) or history of fever during the previous 48 h before consultation, presenting spontaneously to the health centre, were included in the study. After obtaining informed consent from the patient (or from the accompanying parents or legal guardians for children), finger-prick capillary blood samples were obtained for haemoglobin measurement and malaria diagnosis. Two drops of capillary blood samples (approximately 100 µL) were spotted on Whatman 3MM filter paper (GE Healthcare Europe GmbH, Vélizy Villacoublay, France), dried, and stored for molecular analysis. Sociodemographic data, including ethnic origin, recent travel history, ITN ownership and its usage, and clinical history were obtained from the patients or the parents (or legal guardians) of febrile children. Among the patients who reported to own at least one ITN, its use was classified as 'never,' for those who never slept under the bed net at night, 'rarely' for those who slept under the ITN at least once per month, 'frequently' for those who slept under the ITN at least once a week, and 'always' for those who slept under the ITN every night.

4.3. Malaria Diagnosis

The presence of malaria parasites was detected on-site by rapid diagnostic test (RDT) (SD Bioline malaria antigen Pf/Pan test, Standard Diagnostics/Abbott, https://www.abbott.com (accessed on 5 December 2021)) and microscopic examination of Giemsa stained thick and thin blood films, and later confirmed by PCR at the University of Nouakchott Al-Aasriya. The procedures of RDT for malaria, microscopy, and PCR were detailed in previous publications [6,50]. The RDT used in the present study detects

the presence of *P. falciparum*-specific histidine-rich protein 2 and *Plasmodium* genus-specific (i.e., *P. falciparum*, *P. vivax*, *P. ovale*, and *P. malariae*) lactate dehydrogenase circulating in the patients' blood.

4.4. Data Analysis

The proportion of ownership of bed nets was calculated as the number of individuals with at least one bed net in the household over the total number of recruited participants. Proportions were compared using Fisher's exact test. The Spearman's rank correlation coefficient was computed to compare the relationship between the number of ITNs ownership by household and their frequency of use. A two-tailed *p*-value < 0.05 was considered statistically significant.

5. Conclusions

Although dams favour the creation of new breeding sites for *Anopheles* mosquitoes, malaria transmission in Rosso remains very low, most likely due to the frequent use of bed nets by the majority of the local populations and zoophilic preference of *An. arabiensis*. Further epidemiological studies, including entomological surveys, are required in the Sahelian zone of the country, both inland and along the Senegal River, where *P. falciparum* is known to be the predominant *Plasmodium* species, to understand the current malaria situation and implement appropriate malaria control strategies.

Abbreviations

ACT: artemisinin-based combination therapy; HBI, human blood index; IPTp, intermittent preventive treatment in pregnancy; ITN, insecticide-treated bed net; IRN, indoor-residual spraying; LDH, lactate dehydrogenase; LLIN, long-lasting insecticidal nets; PCR, polymerase chain reaction; and RDT, rapid diagnostic test.

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