Institut Sénégalais de Recherches Agricoles

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Fiche Technique

Ecological distribution and population dynamics of Rift Valley fever virus mosquito vectors (Diptera, Culicidae) in Senegal

Biram Biteye, Assane Gueye Fall, Mamadou Ciss, Momar Talla Seck, Andrea Apolloni, Moussa Fall, Annelise Tran and Geoffrey Gimonneau.

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Document presented by:

Biram Biteye[1,2], Assane Gueye Fall[1], Mamadou Ciss[1], Momar Talla Seck[1], Andrea Apolloni[1,3], Moussa Fall[1], Annelise Tran[3,4] and Geoffrey Gimonneau[5,6]

[1]Institut Sénégalais de Recherches Agricoles/Laboratoire National de l'Elevage et de Recherches Vétérinaires BP 2057 Dakar-Hann, Sénégal.

[2]Université Cheikh Anta Diop, Faculté des Sciences et Techniques, Département de Biologie Animale, Laboratoire d'Ecologie Vectorielle et Parasitaire, Dakar, Sénégal.

CIRAD, UMR ASTRE, INRA, F-34398 Montpellier, France.
[4]CIRAD, UMR TETIS, F-97940 Sainte-Clotilde, Reunion Island, France.

CIRAD, UMR INTERTRYP, F-34398 Montpellier, France.

[6]Centre International de Recherche – Développement sur l'Elevage en zone subhumide, Bobo-Dioulasso 01 BP 454, Burkina Faso.

Background:

Many zoonotic infectious diseases have emerged and re-emerged over the last two decades [1,2]. There has been a significant increase in vector-borne diseases due to climate variations that lead to environmental changes favouring the development and adaptation of vectors [3-5]. This study was carried out to improve knowledge of the ecology of mosquito vectors involved in the transmission of Rift Valley fever virus (RVFV) in Senegal.

Methods:

Study area

Three localities, Diama, Dandé Mayo Loboudou (DML) and Younouféré, were selected in the SRD, SRV and Ferlo ecosystems, respectively (Fig. 1). These sites had all been affected recently by RVF outbreaks [6,7]. Diama (16°12′41.4″N, 16°23′31.6″W), is a small village on the bank of the SRD located 28 km east of the town of St-Louis. The main human activities are agriculture and animal breeding. Traditional farming methods are used and herders practice transhumance. DML is a village (15°56′51.7"N, 15°56′22.2"W) in SRV located 6 km from Keur Momar Sarr (KMS) town, near Guiers Lake, an important fresh water reserve. The village belongs to a sylvo-pastoral area located immediately south of the river valley and occupying part of the Sahelian and Sudano-Sahelian region. Extensive farming/pasturage is the main production system in the area. Younouféré village (15°16′08.7"N and 14°27′52.5"W) is located in Ferlo. It is surrounded by small hamlets composed of only a few houses. The area is characterized by a semi-arid steppe and many temporary ponds that are filled by run-off water. These ponds are the main source of water for humans and animals during the rainy season [8,9], and are also important breeding sites for mosquitoes. The Ferlo region is an important transhumance point for livestock (cattle and small ruminants) coming from Mauritania; the livestock proceed south at the beginning of the rainy season and move north during the dry season.

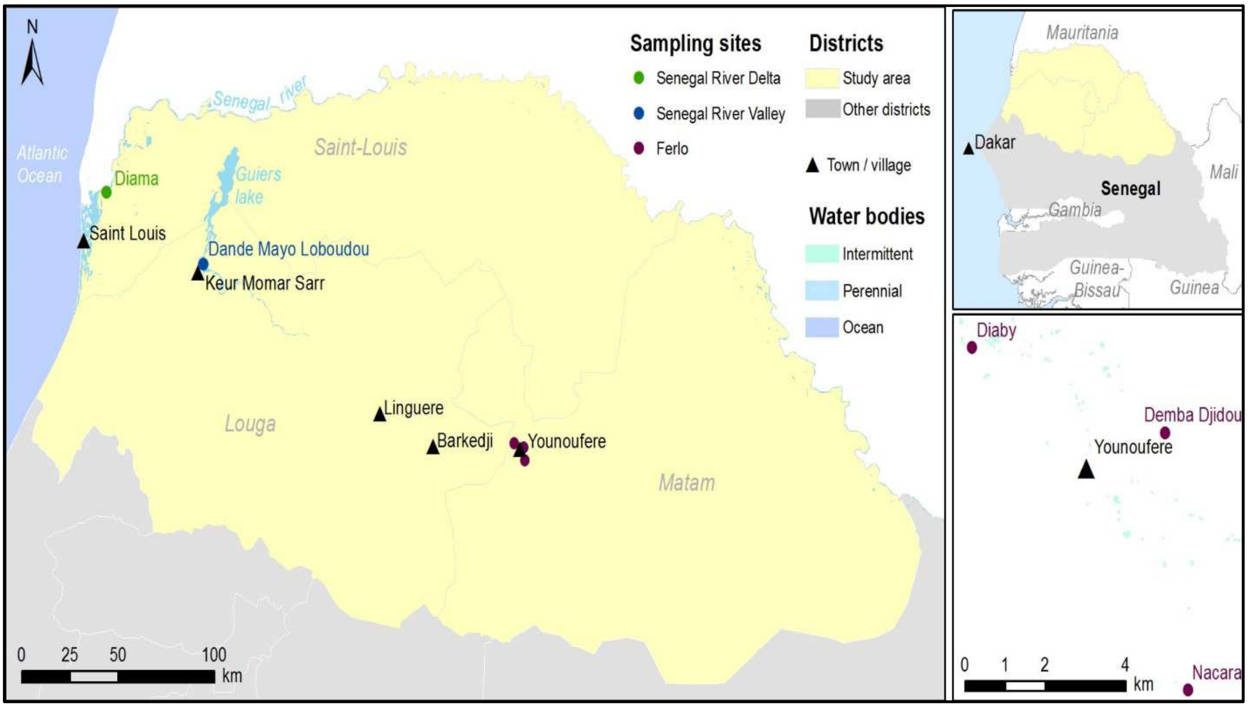

Fig. 1: Location of the three sampling sites in northern Senegal. Top-right corner: Senegal map and area of interest (in yellow). Main figure: triangles represent main towns/ villages nearby the sampling sites, while full circles correspond to the sampling points. Bottom-right corner figure: detail of the positions of the three sampling points in Younoufere

Collection of meteorological data

Local veterinarian officers, who routinely collect daily rainfall data using rain gauges located in each location, provided the rainfall data. Temperature and relative humidity were collected on each site every hour of every day throughout the year using a data logger (HOBO U10 Temp / RH Data Logger, West Sussex, United Kingdom).

Sampling and processing of entomological data

An entomological survey was conducted in 2014 and 2015 during the rainy season (from July to November). Every month, mosquitoes were trapped during two consecutive nights (from 6 PM to 6 AM) in each study site using CO2-baited CDC light traps (BioQuip # 2836Q-6VDC, Rancho Dominguez, USA) placed outdoors. Two traps were set per site at a height of about 1.5 m from the ground: one close to a natural water point (river, lake or pond); another close to a livestock pen. The distance between the water source and livestock pen varied from 100 to 800 m depending on the site. In the field, the mosquitoes collected were killed by freezing in dry ice, sorted by genus on a chill table, put in 15 or 50 ml centrifuge tubes/cryo- tubes and transported in dry ice (-80 °C) to the laboratory where they were identified according to sex and species on a chill table (-20 °C) using morphological keys [10,11].

Statistical analysis

To characterize the different populations of RVF mosquito vectors, ecological variables were used as predictors. Thus for each site, the following indices were calculated: (i) the ecological indices of composition: total (S) and average (Sm) species richness, total (N) and relative (AR%) abundance, frequency of occurrence or constancy (C%); and (ii) the ecological indices of structure: Shannon-Weaver diversity index (H′), maximum diversity index (H′ max), Simpson's diversity index (1-D) and equitability index (E). Non-parametric Kruskal-Wallis, Mann Whitney-Wilcoxon tests, and principal components analysis (PCA) were used to assess differences in species abundances and meteorological parameters (temperature, relative humidity and rainfall) between localities and capture points. The Pearson's correlation test was used to exclude strongly correlated ($r \geq 0.9$) variables from the analysis. A generalized linear mixed model (GLMM) was used to assess the effect of climatic variables [temperature (mean of capture day), relative humidity (mean of capture day) and rainfall (mean andmax. from 6 to 7 days prior to the capture event)] on mosquito abundances; site and date of capture were considered as random effects. The collected data set on the mosquitoes' temporal abundances was randomly divided into a training set and a test set. The training set was used to build the model and the test set to validate the best model based on the Akaike information criterion (AIC) [12] for each species. A random selection was performed and 2/3 (67%) of the entire data set was assigned to the training set and 1/3 (33%) to the test set. All of the analyses were carried out with R software [13], lme4 package [14] was used to fit the GLMM, ade4 package [15] to fit the PCA and vegan package [16] to fit the ecological indices.

Results:

A total of 355,408 mosquitoes belonging to 7 genera and 35 species were captured in 200 night-traps. RVFV vectors represented 89.02% of the total, broken down as follows: *Ae. vexans arabiensis* (31.29%), *Cx. poicilipes* (0.6%), *Cx. tritaeniorhynchus* (33.09%) and *Ma. uniformis* (24.04%). Comparison of meteorological indices (rainfall, temperature, relative humidity), abundances and species diversity (Table 2) indicated that there were no significant differences between SRD and SRV ($P = 0.36$) while Ferlo showed significant differences (Fig. 2) with both ($P < 0.001$).

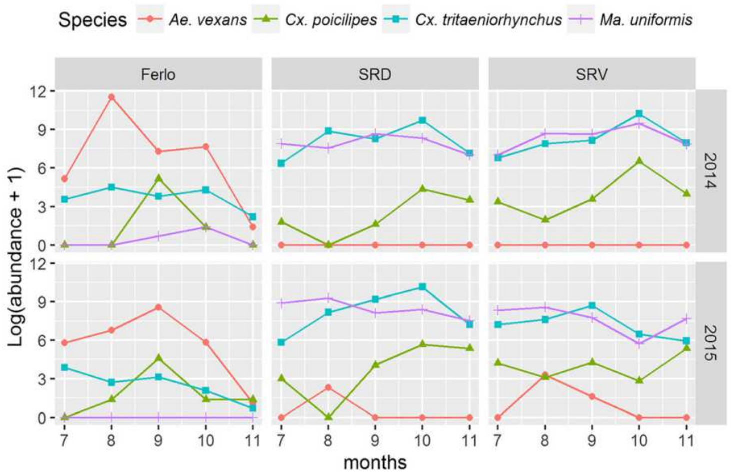

Fig. 2 Seasonal population dynamics of RVF mosquito vectors in northern Senegal per year (row) and site (column). On the x-axis we report the time (months) of mosquitoes' capture; on the y-axis the corresponding abundance (logarithmic scale); each color correspond to a vector species. *Abbreviations*: SRD, Senegal River Delta; SRV, Senegal River Valley

Mosquito collection increased significantly with temperature for Ae. vexans arabiensis (P < 0.001), Cx. tritaeniorhynchus (P=0.04) and Ma. uniformis (P=0.01), while Cx. poicilipes decreased (P = 0.003). Relative humidity was positively and significantly associated with the abundances of Ae. vexans arabiensis (P < 0.001), Cx. poicilipes (P = 0.01) and Cx. tritaeniorhynchus (P = 0.007). Rainfall had a positive and significant effect on the abundances of Ae. vexans arabiensis (P = 0.005); (Table 3). The type of biotope (temporary ponds, river or lake) around the trap points had a significant effect on the mosquito abundances (P < 0.001).

Table 2 Ecological indices of composition and structure by study site in 2014–2015

Locality		Diama (SRD)		DML (SRV)		Younouféré (Ferlo)	
Year		2014	2015	2014	2015	2014	2015
Abundance (N)		51,058	75,707	81,514	30,808	108,475	8551
Total richness (S)		22	21	18	19	23	23
Average richness (Sm)		9.85	9.55	8.6	8.35	3.57	3.82
Maximum diversity (H′ max)		4.459	4.392	4.169	4.247	4.523	4.523
Shannon index (H′)		1.037	1.087	1.318	1.33	0.254	0.332
Simpson's index (1-D)		0.446	0.427	0.346	0.34	0.921	0.898
Equitability index (E)		0.233	0.247	0.316	0.313	0.056	0.073
AR (%)	*Ae. vexans arabiensis*	0	0.012	0	0.097	96.19	79.04
	Cx. poicilipes	0.235	0.767	0.974	1.252	0.165	1.251
	Cx. tritaeniorhynchus	57.581	52.94	46.1	33.57	0.228	1.064
	Ma. uniformis	32.306	36.659	34.71	46.42	0.003	0.02
C (%)	*Ae. vexans arabiensis*	0	20	0	25	68.33	61.66
	Cx. poicilipes	75	65	90	70	16.66	15
	Cx. tritaeniorhynchus	100	100	100	95	56.66	25
	Ma. uniformis	100	100	100	95	6.666	1.66

Abbreviations: *AR* relative abundance, *C* frequency of occurrence or constancy

Table 3 Poisson-GLMM abundance model used for each of the four potential RVFV vectors

	Regression coefficient	SE	*Z*-value	*P*-value
Ae. vexans arabiensis				
Intercept	-23.08933	4.8033	-4.807	1.53e-06
Temperature (mean of capture day)	0.59791	0.15218	3.929	8.53e-05
Humidity (mean of capture day)	0.08697	0.02454	3.543	0.000395
Rainfall (mean from 6 to 7 days prior to the capture event)	0.07836	0.02837	2.762	0.005737
Cx. poicilipes				
Intercept	11.06897	5.24993	2.108	0.035
Temperature (mean of capture day)	-0.54716	0.18934	-2.89	0.00385
Humidity (mean of capture day)	0.06626	0.02797	2.369	0.01783
Cx. tritaeniorhynchus				
Intercept	-5.88329	3.27343	-1.797	0.07229
Temperature (mean of capture day)	0.20359	0.10296	1.977	0.04800
Humidity (mean of capture day)	0.04447	0.01672	2.659	0.00783
Ma. uniformis				
Intercept	-9.380981	5.716084	-1.641	0.1008
Temperature (mean of capture day)	0.242669	0.099457	2.44	0.0147
Humidity (mean of capture day)	-0.010763	0.019884	-0.541	0.5883
Rainfall (max from 6 to 7 days prior to the capture event)	0.005822	0.00669	0.87	0.3842

Abbreviation: *SE* standard error

Conclusions:

In terms of species diversity, the SRD and SRV ecosystems are similar to each other and different from that of Ferlo. Meteorological indices and the type of biotope (river, lake or temporary pond) have significant effects on the abundance of RVFV mosquito vectors.

Keywords:

Ecology, Mosquito vectors, Rift Valley fever virus, Senegal, Biotope, Meteorology

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