Malaria vector density entomological surveillance system evaluation, Zambezia, Mozambique, 2017-2019

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ABSTRACT

Introduction: Vector density is the degree of domiciliation of malaria vectors that influence the vectorial capacity of mosquito populations in different regions and at different times. To understand whether the system meets the objectives that were set out, the study was undertaken to evaluate the entomological vector density surveillance system (VDESS) of the National Malaria Control Programme in Zambezia Province. June 2017-July 2019.**Methods:** For evaluation of the surveillance system, data were extracted from the entomological surveillance system of Zambezia Province in Mozambique from 2017 to 2019. The evaluation was based on criteria defined in the Updated Guidelines for Evaluating Public Health Surveillance Systems from the Centers for Disease Control and Prevention (CDC). Simplicity, flexibility, data quality, acceptability, representativeness, and sensitivity attributes were evaluated. **Results:** The database had 25,317 records of *Anopheles* mosquitoes, with morphological identification, from June 2017 to July 2019. The VDESS presented ten unfilled variables and required ≤ 2 technicians for data collection. About 99.98% (253,202/253,230) of the fields were filled, rating it as acceptable and the system was able to report data to the NMCP within a period of 30 to 90 days and was rated stable. The system was rated as sensitive as it had been programmed to capture and identify 100% of *Anopheles species.* **Conclusion:** The VDESS was useful, simple, sensitive, stable, acceptable, and with excellent data quality. This system helped inform the quality of activities influencing malaria vector control measures and, therefore, contributed to strengthening efforts to eliminate malaria in the country.

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KEYWORDS: Mosquito vectors, Anopheles, Entomology, Mozambique

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Introduction

Malaria is a major cause of morbidity and mortality in developing countries [1,2]. According to the World Health Organization (WHO), in 2018 there were about 228 million diagnosed cases of malaria and 405,000 deaths from malaria worldwide, with 93% of cases and 94% of deaths occurring in the African region [3]. The genus *Anopheles gambiae s.l.* and *Anopheles funestus s.l.* are the main and most efficient malaria vectors in sub-Saharan Africa and their transmission efficiency is mediated by behavioural adaptation and in-home feeding with humans [4]. The main vectors in Mozambique are *An. funestus s.s.* and subspecies of *Anopheles gambiae complex, An.arabiensis*which is more prevalent in the south of the country and *Anopheles gambiae s.s.* in the north [2].

Malaria is endemic in Mozambique where its transmission occurs throughout the year with a seasonal peak during the rainy season from December to April [1]. Several factors may contribute to the increased transmission, including that Mozambique is prone to climate-related natural disasters such as drought and flooding, specifically in low coastal areas and along large rivers [2].

Malaria in Mozambique is responsible for 42% of deaths in children under 5 years and *Plasmodium falciparum* is the parasite responsible for 90% of all infections followed by *P. malariae and P. ovale* with about 9% and 1% respectively [1,3].

Indoor residual spraying (IRS) and insecticide-treated nets (ITNs) remain the primary mosquito vector control interventions in many parts of the world, including sub-Saharan Africa, where malaria continues to be a major public health concern [5].

The effectiveness of these interventions depends on vector density data to inform correct insecticide selection and intervention based on entomological context [5]. Malaria entomology is the study of the biology and ecology of mosquitoes that transmit malaria and its objective is to understand the relationships between the vector, its ecology and behavior, the parasite and the host, to formulate and implement effective vector control strategies [6].

Entomological surveillance is the regular and systematic collection of entomological data for their analysis and interpretation for planning, monitoring, and evaluating interventions related to vector control that will influence decision-making [6,7]. All surveillance activities should be linked to program decisions to ensure the deployment of optimal vector control interventions [7].

In Mozambique, entomological surveillance is a core activity implemented by the National Malaria Control Program (NMCP) alongside activities such as IRS and distribution of ITNs [1]. These activities produce results on vector density and specific composition, quality control of spraying and residual insecticides on sprayed surfaces and susceptibility of vectors to insecticides in different sentinel posts [1].

The vector density data system evaluated in this analysis was part of the survey of routine sentinel sites that made regular long-term observations (monthly, quarterly or annual) at fixed locations aiming to identify any change in vector species density and composition, behaviour, susceptibility to insecticides and even infection rates, which may explain any epidemiological risk, trends in malaria transmission and thus be able to propose an appropriate response [7].

For vector density determination, the female *Anopheles* mosquito is collected as it is responsible for malaria transmission. The methods used for the collection of vector density data in Zambezia Province were Pyrethrum Spray Catches (PSCs) and Center Disease Control (CDC)-Light Trap (LT). PSC is a technique that uses a spray of a pyrethroid insecticide with no residual effect and is applied to the main rooms of houses in the early hours of the morning with the floor all covered in white for the mosquitoes to fall on.

The most commonly used technique for collecting mosquitoes in the province was the CDC-LT. CDC-LT is a technique that allows the collection of biting mosquitoes indoors and outdoors with minimal risk of exposure for people who voluntarily sleep under a mosquito net.

The mosquitoes are attracted by the glow of the light at night which causes them to enter the glass attached to the trap where they will be exposed to a strong downward air current produced by an electric motor fan.

This study could allow the identification of strengths and weaknesses and propose measures to improve the entomological vector density surveillance system this study aimed to evaluate the system of vector density surveillance in Zambezia Province between 2017 and 2019.

Methods

This study was conducted in Zambezia Province, located in the center of Mozambique with 22 districts [8]. The Entomological activities including vector density, were carried out throughout the year. The entomological activities, including a surveillance system of vector density, were assessed from July 2017 to June 2019, using secondary entomological surveillance data provided by the partner, PMI Vector Link Mozambique, responsible for entomological activities in Zambezia province.

The data produced by the province was used to produce information for decision-making by the NMCP in conjunction with the partner to evaluate the system. The evaluation of this system followed the Centers for Disease Control and Prevention (CDC) updated 2001 guidelines for evaluating public health surveillance systems [9]. The attributes simplicity, flexibility, data quality, acceptability, representativeness, stability and sensitivity were used for the evaluation of the system (Table 1).

Attributes evaluated

Simplicity

The simplicity of a public health surveillance system concerns its structure and ease of operation [9]. To evaluate the simplicity, the number of staff involved in data collection and the number of variables in the database were assessed. The system was classified as simple if it involved ≤ 2 people in the field for data collection and complex if it had >2 people in the field. Regarding the number of variables, the system was classified as simple if had ≤ 14 variables in the database and complex if had >14. We considered 14 variables to classify simplicity according to the number present in the database of the NMCP of the Ministry of Health.

Acceptability

Acceptability reflected the willingness of people and institutions to participate in the surveillance system [9]. The acceptability was evaluated using the degree of database completeness and was classified as excellent ≥90%, good 80-90% and low <70%.

Data quality

The data quality reflected the completeness and validity of the data recorded in the vector density surveillance system [9]. For data quality, the percentage of unfilled variables was assessed and graded as follows: Excellent= 0%, Good= <10%, Regular= 10 to 20 %, Poor >20%.

Representativeness

A representative public health surveillance system accurately describes the occurrence of a health event over time and its distribution in the population by place and person [9]. With regard to representativeness, the ability of the system to collect data on different types of Anopheles mosquito species regardless of period and location.

Flexibility

Surveillance system that can adapt to changing information needs or operational conditions at little additional cost, in terms of time, personnel, or financial resources [9]. For flexibility, the capacity of the system to adapt to the appearance of new vectors was evaluated, and the system was classified as flexible or not.

Stability

Stability refers to the reliability (i.e., the ability to collect, manage, and provide data correctly without failure) and availability (the ability to be operational when needed) of the public health surveillance system [9]. In relation to stability, the time taken to send data to the NMCP for the production of reports was evaluated and the system was classified as follows: <30 days = Excellent, 31-90 days = Good and >90 days = Poor.

Sensitivity

It is the capacity of the system to capture and identify all positive cases. For the system's sensitivity, it can capture and identify all types of Anopheles mosquitoes, being considered as a parameter for its measurement 100% sensitive.

Results

Description of Zambezia's entomological vector density surveillance system

The collection of vector density data is a process that took place in all months and throughout the country in areas considered intervention and control districts. Zambezia province had eight sentry posts, of which five were intervention districts where IRS was used, two with no IRS intervention and one control district. The five districts where IRS was applied are Maganja da Costa, Milange, Morrumbala, Mopeia and Mocuba. The districts where IRS was not applied are Lugela, Molevala and Quelimane which are considered control districts.

After sample collection, the Gillies & Coetzee 1987 key was used by the entomology technicians for the morphological identification of the anopheles species captured. After sample identification, the information was entered into an Excel database by the same technician who collected the mosquitoes in the field.

The Excel format vector density database was composed of the following variables: province, district, mosquito collection techniques, month, date, house, tube number, morphological identification, physiological status and geographic coordinates of the collection site.

After the data was entered into the database, the samples were sent to the Mozambique National Institute of Health (NIH) for molecular identification. After molecular identification, the results are sent back to Zambezia province without any need to go through the NMCP for approval (Figure 1).

Attribute results

Simplicity: According to the database, it takes 2 people to carry out the field activities. Figure 2 shows the representation of the data collected over the different months in different years, and that the database did not change over the three years for which the analysis was done, thus maintaining the ten variables. The vector density surveillance system was classified as simple.

Acceptability: The database had 25,317 mosquito records with morphological identification and ten variables to fill in the information collected in the field. The database has a total of 253,230 fields, of which 99.98% (253,202/253,230) were filled. According to the classification, the system was rated as acceptable.

Data quality: Of the ten variables present in the database, three were fully completed, namely: province, district and month of data collection. The remaining variables were not fully completed as they all had 0.02% of fields not filled in namely: neighbourhood, date, collection technique, house number, sample and morphological identification.

When comparing the variables tube (0.0003%), morphological identification (0.0003%) and sample (0.0002%) which are interrelated, some differences in terms of percentages of filled fields were noted, although they were not representative. The data quality of the system was considered good.

Representativeness: The system was able to identify the main vectors of malaria in all districts where entomological activities take place. It was possible to identify the vectors during the months corresponding to analyzed period, of which 21,853 mosquitoes and 88.1% (19,252/21,853) for *Anopheles funestus* and 11.9% (2,601/21,853) for *Anophles gambiae* (Figure 2).

Figure 2 shows the representativeness of the system, presenting data collected on different vectors from the study period. The data collected allows the production of information that can inform about the quality of the interventions that are being carried out in the districts. As the system was able to capture and identify malaria vectors in all districts and all evaluation periods, the system was classified as representative.

Flexibility: Regarding the flexibility of the system, it showed the ability to adapt to the appearance of possible new malaria vectors in the two different seasons (winter and summer). During the period under analysis, the system was able to identify nine possible new vectors of malaria, namely, *Anopheles ziemanni, An. tenebrosus, An. squamosus, An. rufipes, An. pretoriensis, An. pharoensis, An. natalensis, An. dancallicus, An. coustani.* Due to its responsiveness to the appearance of possible new vectors the system was classified as flexible (Figure 3)

Sensitivity: The system was programmed to identify all possible vectors of malaria in this case the Anopheles mosquito. In the present study it was possible to identify the main possible vectors of malaria. The system was rated 100% sensitive.

Stability: The system has been available regularly over a period of 31-90 days (Good), during which time the data has been used for reporting and presentation to entomology technical groups held every three months. According to the classification the system was considered stable.

Usefulness: The entomological surveillance system of vector density in Zambezia was rated as useful as it met its objectives set by the NMCP and the system has proved to be important in the public health interventions made using its data, assisting in decision making.

Discussion

This is the first time this system has been evaluated, and there is also limited literature that could help to compare with the results obtained. According to CDC 2001 guidelines, simplicity closely linked to the acceptance of a system, and thus the entomological surveillance system of vector density presented good acceptability with the database record reaching 99.98% [9].

Factors such as the motivation and training of the technicians carried out regularly made the system better known and more acceptable to the technicians who integrated it.

The simplicity of the system also influenced the quality of the data, and the classification of the system was considered good in terms of variables filled in. The quality and acceptability results revealed the level of commitment of the entomology technicians in Zambezia province to carry out activities related to the entomological surveillance system of vector density.

The system was representative, capturing and identifying malaria vectors regardless of time, place and period. The system´s representativeness allowed for the characterization of the malaria vector population in a given region, thus informing malaria control strategies according to each type of vector found in a region [10].

The system was classified as simple, and this allowed it to be flexible in capturing and identifying new vectors, indicating that it was a reliable system.

Having a surveillance system that responds in a timely manner will allow the system to respond to the needs of the program, providing timely information and timely decision-making. This system was not timely in sending data collection sheets in the NMCP according to the set requirements, as other provinces had done after 7 days.

The contributing factor may have been those entomological activities in the province were under the tutelage of a partner that worked together with the NMCP, providing ideal conditions for the performance of activities related to vector density, such as the availability of insectary conditions and field material.

The system was stable since it presented results of the vector density within 31-90 days, and this was sufficient to present the results in the technical group meetings that served as the decision-making process. The system was useful because it assisted in the decision-making process and in designing strategies to combat malaria in the country through vector control aimed at eliminating malaria by 2030 [10].

The entomological vector density surveillance system was complemented by other activities such as the study of the behavior and resistance of vectors to insecticides that have been used. In Mozambique, studies related to entomological surveillance of vector density have been scarce or almost non-existent in the country, which may have somewhat hampered the discussion of the results obtained.

A few studies related to the evaluation of the entomological surveillance system of vector density have been carried out globally and, these studies could help to improve the functioning of the system.

Conclusion

The entomological surveillance system of vector density was useful, simple, representative, sensitive, flexible, stable, acceptable, and with good data quality. The entomological data system meets the objectives of the NMCP which is to produce entomological data about the impact of control measures on malaria vectors and, therefore, contribute to strengthening the measures to eliminate malaria in the country. In order for the data to reach the NMCP promptly, it is recommended to set up an online data submission system, which will also include all provinces of the country.

What is known about this topic

- The control of malaria vectors in Mozambique is done through ITNs and IRS
- The *An. funestus s.l.* is the most abundant vector, in mosquitoes collected from resting indoors.

What this study adds

- The data collection method of vector density data in Zambezia Province were PSCs and CDC-LT
- The entomological surveillance system of vector density was shown to be able to identify and capture all the Anopheles mosquitoes responsible for malaria transmission and allow the NMCP to design programmes for vector control

Competing interests

The authors declare no conflicts of interest.

Authors´ contributions

Fabião Edumundo Maússe, responsible for data analysis, interpretation and manuscript writing. Kennysson Varela, provide the database and reviewing the manuscript. Erika Valeska Rossetto supports the design of the evaluation methodology. Baltazar Neves Candrinho supervised and approved the final version. Nelson Cuamba, Cynthia Semá Baltazar, Jahit Sacarlal and Erika Valeska Rossetto was responsible for reviewing the protocol, the report and the final version of the manuscript.

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Tables and figures

Table 1: Evaluation of the entomological surveillance system of vector density of the National Malaria Control Program, Zambezia Province, Mozambique, 2017-2019

Figure 1: Flow chart of entomological surveillance of vector density

Figure 2: Main vectors in the period June 2017-July 2019

Figure 3: Vector collection period in summer-winter season-Milange, 2018-2019

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Table 1: Evaluation of the entomological surveillance system of vector density of the National Malaria Control Program, Zambezia Province, Mozambique, 2017-2019

Attribute	Criteria to be analyzed	Definition	Source of information	Parameter	Score reached	Final classification
Simplicity	Number of staff involved in the data collection system	Structure and facilities for System operation	Entomology database	≤ 2 simple; > 2 complex	≤ 2	Simple
	Number of variables		Entomology database	≤ 14 simple; >14 complex	10	
Acceptability	Degree of completion	People's willingness institutions to participate in the system	Entomology database	Excellent≥90%; Good-80 to 90%; Low <70%	99.98%	Excellent
Data quality	Percentage of unfilled variables	Completeness and validity of data recorded in the system	Entomology database	Excellent= 0%; Good= <10 %; Regular= 10 to 20%; Poor >20%	> 0% but less than 10	Good
Representativeness	The ability of the system to collect data after the change of station, independent of the location Summer/Winter	Describes precisely the occurrence of a health event over time and its distribution in the population by place and person	Entomology database	1-Representative; 2-Non-representative	Can capture and identify the main malaria vectors 1-Representative	Representative
Flexibility	The ability of the system to adapt to the emergence	The system that can adapt to changes in	Entomology database 2017-2019	1-Yes-Flexible; 2-Non-Flexible	1-Yes	Flexible

Table 1: Evaluation of the entomological surveillance system of vector density of the National Malaria Control Program, Zambezia Province, Mozambique, 2017-2019

Attribute	Criteria to be analyzed	Definition	Source of information	Parameter	Score reached	Final classification
	of new vectors	information needs				
Stability	Time to send data to the NCPM for the production of reports	Availability of the system	Reports	Time to send data to the NMCP for reporting: <30 days = Excellent; 31-90 days = good; >90 days = Poor	31-90 days	Good
Sensitivity		It was not necessary to calculate the sensitivity because the system is programmed to record only positive cases and thus the system 100% sensitive.			100%	Sensitive

Source: Attributes adapted from CDC-2001 based on NMCP classification criteria

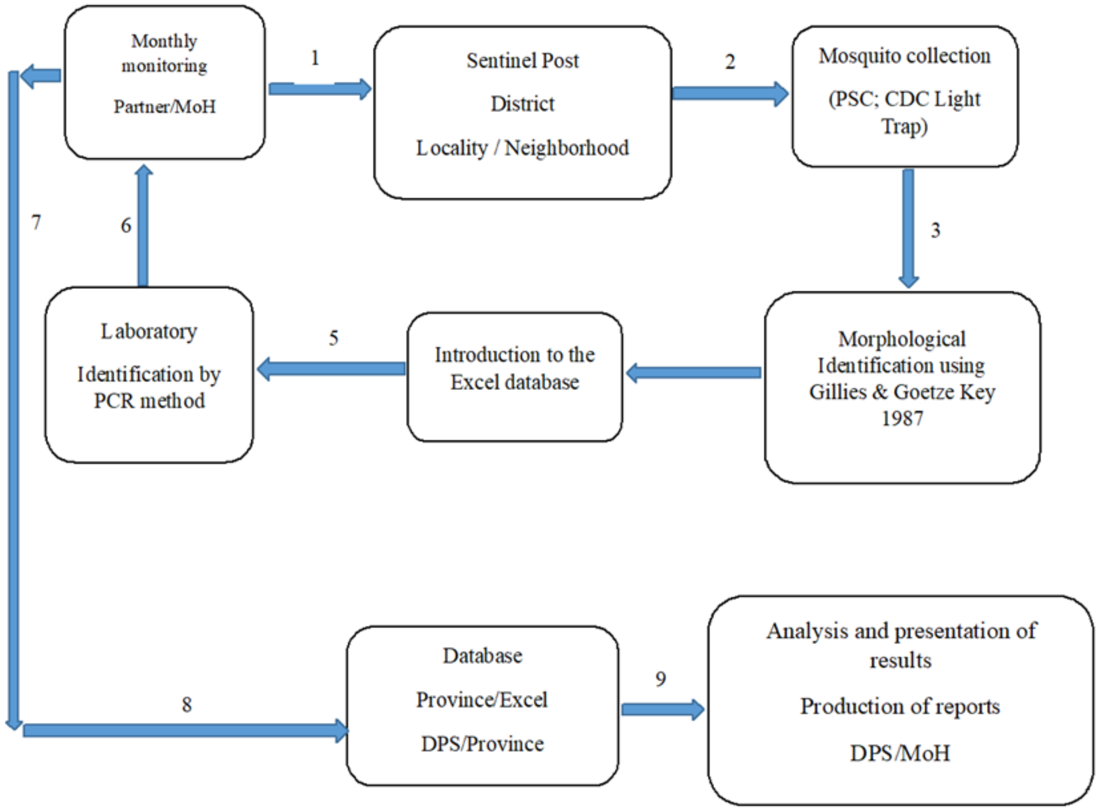

Figure 1: Flow chart of entomological surveillance of vector density

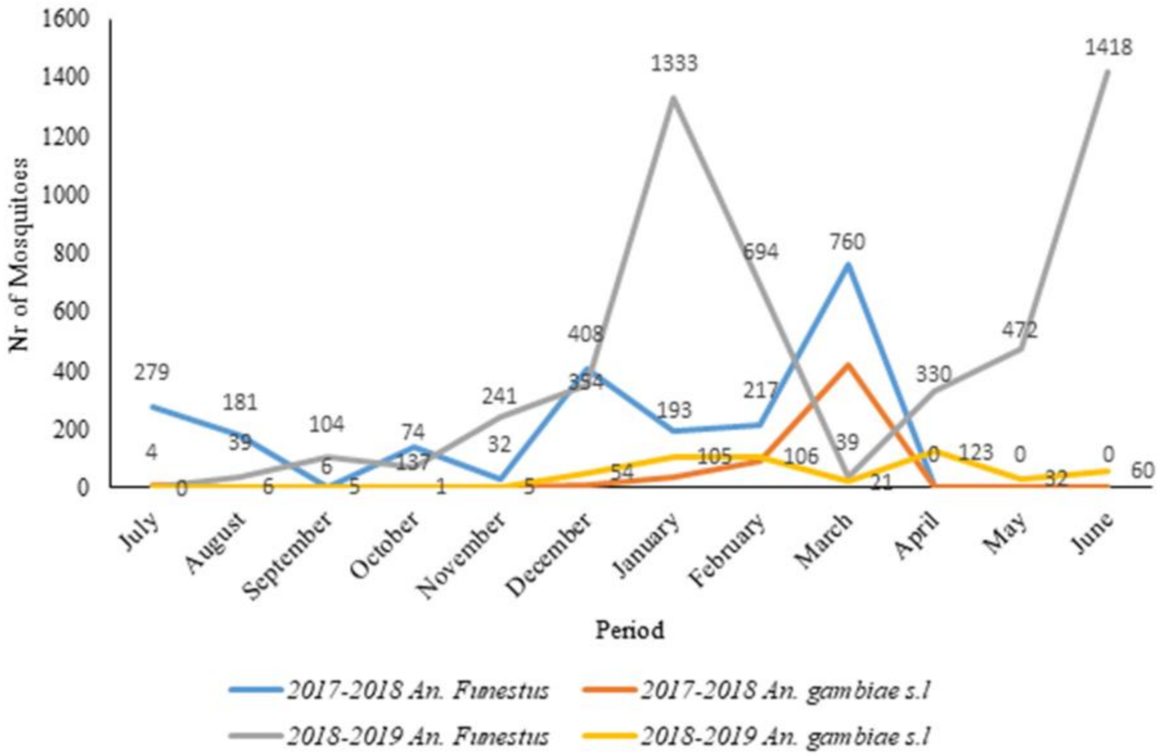

Figure 2: Main vectors in the period June 2017-July 2019

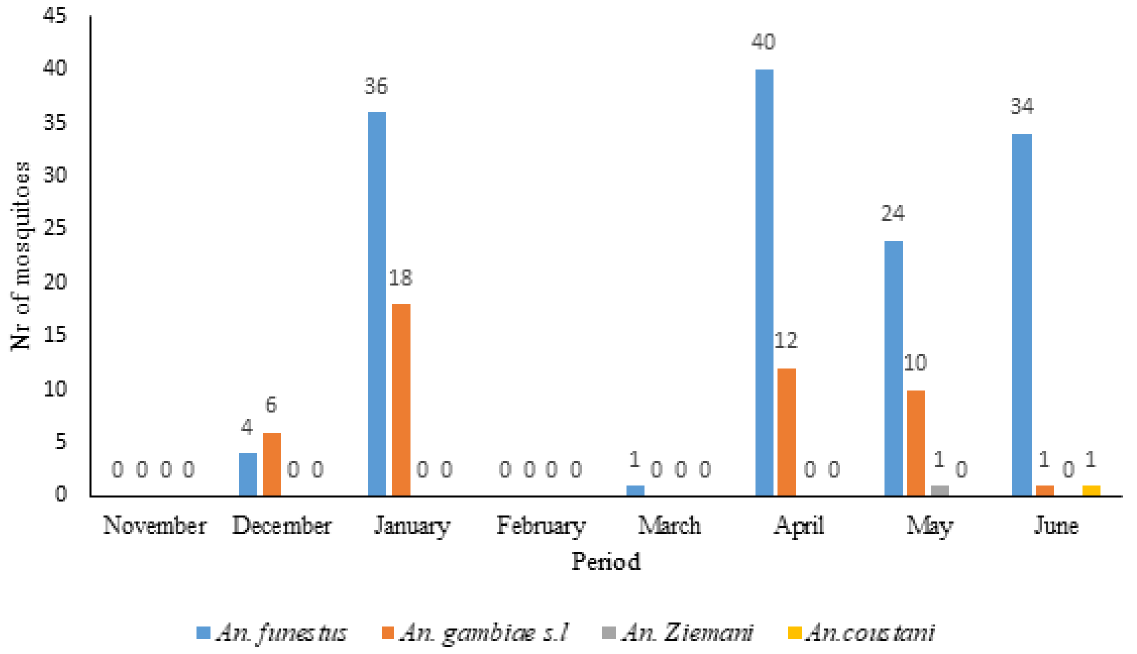

Figure 3: Vector collection period in summer-winter season-Milange, 2018-2019