# MALARIA ENTOMOLOGICAL PROFILE

## DECEMBER 2017

**National Malaria Control Programme**

**Community Health Sciences Unit**

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**MALAWI**

## Table of Contents

**Acronyms**

| | |
|---|---|
| GIS | Geographical Information System |
| IRS | Indoor Residual Spray |
| IVM | Integrated Vector Management |
| NMCP | National Malaria Control Programme |
| LSM | Larval Source Management |
| MoH | Ministry of Health |
| WHO | World Health Organization |
| EIR | Entomological Inoculation Rate |

**Forewords**

The Ministry of Health through the National Malaria Control Program (NMCP) Developed the National Malaria Strategic Plan (MSP) which outlines the strategies and targets for malaria control with emphasis on universal access to diagnosis, treatment and malaria prevention. In line with this, to successfully Control malaria Vectors It is imperative to have good knowledge of the vectors. To have all the available Information about the malaria vectors. NMCP took the initiative of putting together Malaria Entomological Profile for the country (2017). The purpose of the profile is to guide the Ministry in implementation of recommended and effective malaria vector control activities. Knowledge of vectors is important in malaria vector control interventions.

This malaria entomologic profile gives fundamental Information on vectors. Such details as vector behaviour, resistance status and vector presence and their vectorial capacity. The profile will assist malaria Control program Implementers in decision making about appropriate vector control approaches as well as in resistance management

Currently one of the biggest challenges, in vector control is lack of reliable or unavailability of information on malaria vectors and this profile makes available such information  ensure efficient and effective ways of implementing malaria vector control interventions.

I therefore thank Global fund and stakeholders for their valuable contributions that have resulted into development of this document

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Date

**Acknowledgement**

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We greatly appreciate the contributions of various stakeholders who participated in the Malaria Vector Control Technical Working Group and stakeholders consensus meetings and reviewed this document: , Mr John Chiphwanya, , Mr Shadreck Mulenga, Mr. (Pius Masache (USAID/PMI); Mr Charles Yuma and Jones Labana , (NMCP), Dr. Themba Mzilahowa (MAC and Laston Sitima (MOH).

**Executive Summary**

Malaria transmitted by mosquitoes of the genus Anopheles accounts for a larger proportion of deaths in Malawi, members of the *Anopheles gambiae* species complex and *Anopheles funestus* species group are the principal malaria vectors in Malawi. To successfully Control Malaria and eliminating transmission requires knowledge of the vectors biology. Malaria control efforts have failed due to lack of information about Anopheles mosquito species. A thorough knowledge of the diversify of vector species available, resistance to insecticides, feeding behaviour, and other malaria transmission indices such as entomologic inoculation rate, human blood index, sporozoite rates are critical to putting up better control /prevention strategies. The purpose of this entomologic profile is to put together information from published and unpublished documents on diversity of vectors found in Malawi, where they are found and which period of the year do they occur, their feeding and resting behaviour, transmission indices and susceptibility status to insecticides. All data from published and unpublished sources available were put into a database. Details recorded for each data source were the locality, latitude/longitude, time/period of study, species, abundance, sampling/collection methods, species identification methods, insecticide resistance status and transmission indices. All information was gathered from 71 documents. the most common vector species are *An. gambiae* s.s, *An. funestus* and *An. arabiensis*. The dominant vector being *An. funestus* followed by *An. gambae* .Light traps pyrethroid knock down sprays, larval collections, and human landing catches were the most common catching methods. Only 4 of the data sets reported on sporozoite analysis and entomological inoculation rate (EIR), this points to the lack of such critical information. Resistance to pyrethroid was reported throughout the entire country. As most of the information does not cover the entire country it is important for the country to establish entomological surveillance system. This is important for successful malaria vector control programmes.

## 1.0 Introduction

Successful malaria control cannot be attained without good data/information on malaria vectors. The draft Malaria Strategic Plan (MSP) and the Integrated Vector Management (IVM) strategy emphasizes on the importance of vector monitoring. Vector related challenges in malaria control in Malawi can be overcome or mitigated by vector monitoring in the control (Pemba & Kadangwe, 2013).

While some information is available regarding insecticide resistance in malaria vectors in Malawi (Wondji, Coleman et al., 2012; Vezenegho, Chiphwanya et al., 2013; Pemba & Namangale 2013; Chiumia et al. 2016), to successfully control malaria there is need for more aspects regarding malaria vectors in the country, issues related to resistance mechanisms, *Anopheles* malaria vector species compositions, spatial and temporal distribution, vectorial capacity and competencies, feeding behaviour, lifestyles and histories are all necessary but not fully investigated /researched in Malawi hence directly and indirectly affecting malaria control outcomes. Without such information it is impossible to predict outcome of intervention programs, besides determining what need to be focused on in malaria vector control to get the desired impact.

The vector control strategies in Malawi include the use of insecticide treated nets (ITNs), indoor residual sprays (IRS) and Larval Source Management (LSM) on a small scale. Before 2007, ITN coverage was very low in Malawi. No district had more than 2% of its population protected by ITN. In 2008, first free mass distribution of long-lasting insecticide nets (LLIN) was launched, targeting children and pregnant women. By 2010, ITN coverage increased nationwide and over 20% of the population in each district was protected by ITN (NMCP, 2010). By 2015 coverage reached over 70% in most districts (NMCP, 2015).

The Ministry of Health (MoH) launched its first IRS pilot project in Nkhotakota district in 2007. Between 2007 and 2009, approximately 127, 000 houses were protected, covering over 0.5 million residents (Okiro et al., 2013). Between 2010 and 2011, IRS activities were scaled up to other five districts and an estimated 430,000 households were protected with 2.7 million people (NMCP, 2012). The development of insecticide resistance in malaria vectors to pyrethroids necessitated the need to use organophosphates in IRS (Hunt et al., 2010; Skarbinski et al., 2012; Chanda et al., 2015). Due to high cost of organophosphate insecticides, Malawi has abandoned IRS programme as of 2017 (Okiri et al., 2013; Chanda et al., 2015).

LSM was a major malaria vector control strategy in the colonial days but currently, it is being implemented on trial basis at a small scale in some parts of the country. In the old days they used oils and chemicals while in the current situation the use of microbial larvicides dominates (Pemba et al 2013).

To successfully implement the vector control strategies above, a thorough understanding of the local vectors is required hence; the Malawi Government has put together a comprehensive malaria entomological profile for the country. This profile is to be used to come up with appropriate approaches to vector control including insecticide resistance management.

This entomological profile includes some key information on:

i) Malaria vector species found in Malawi , where they are found and what time of the year they are most abundant,
ii) Malaria vector species bionomics which include life histories and strategies such as aspects of life cycles, what micro environmental conditions influences their presence, how do they interact with other organisms such as humans and other vertebrates for their successful life, how do they feed, disperse, and what are their survival strategies. All aspects of their biology that have an impact on malaria transmission are considered besides their genetics.
iii) The profile includes details on susceptibility and resistance to various classes of insecticides used in malaria vector control.
iv) Most importantly an *Anopheles* is of concern or importance to malaria transmission if such a species has known vectorial competency. This profile includes species and locality malaria transmission indices as indicated by entomological inoculation rates, sporozoite rates etc.

## 1.1 Objectives and Scope of Work

This document mainly aims at establishing a malaria vector profile for Malawi purposed for development and implementation of effective interventions that will help in malaria elimination.

The country entomological profile specifically aims to achieve the following:

a. Provide a map of malaria vector species spatial distribution in Malawi

b. Establish the bionomics of malaria vector species (feeding and resting behaviour, ecology, abundance and their seasonal variability) across Malawi.
c. Determine malaria transmission indices (sporozoite rates, entomological inoculation rates and human blood index) across Malawi
d. Recommend varying malaria vector control strategies for Malawi basing on the findings such as species composition, behaviour and locality.

## 2.0 Design and Methodology

To come up with the entomological profile the following approaches were used:

1) Published literature review
2) Information from existing reports/records, and data bases

The methodical design was based on the premise of effectiveness and cost saving. There was a systematic way to maximize the level of rigor and reliability of product by employing well versed team of entomologists all of them with extensive experiences in the field of malaria entomology.

The approaches necessitated a combination of tools to strengthen the credibility by providing multiple sources of data and methods for collecting them. Thus, triangulation of these data sets was built into the design of the study to ensure that the inferences and conclusions drawn from them were based on professional validity.

The consultative process only included experts and stakeholders who have wider and deeper insights based on their undisputed involvement in malaria entomological work.

### 2.1 Data Mining and Documents Review

Databases and search engines useful in academic setting for finding and accessing articles in academic journals, repositories, archives, or other collections of scientific and other malaria entomology articles were drawn. These provided larger and higher-quality quantitative data.

- As the distinction between a database and a search engine is unclear for these complex document retrieval systems, reputable published list of databases were the only ones searched.
- A list of stakeholders involved in relevant work that generate entomological data necessary for entomological profile was drawn and contacted to share the data in their possession. This list of participants was mostly drawn from the Malaria vector technical working group.

### 2.2. Expert Stakeholders Participation

The overriding goal of the consultations was to initiate dialogue and sustain relationships with experts and stakeholders to provide opportunity for contributions. The specific objectives of the consultations were to:

1. Provide a forum for the technical experts to give honest feedback and suggestions on the profile.
2. Document and report stakeholder responses and recommendations for incorporation into profile.

### 2.3.1. Data Collection Instruments and Reviewing of Documents

Data was obtained from both published documents (journal articles, thesis/dissertations as well as book chapters) and unpublished documents (technical reports). These were collected from research institutions, universities or through online searches using the following key words malaria vector species/distribution, anopheles, entomological inoculation rate (EIR), sporozoite rate (SR), human blood index (HBI), insecticide resistance (IR) status with Malawi accompanying every keyword. Each document output was abstracted.

Malawiana, an online database housed at Chancellor College by the University of Malawi, was also used as it archives all published and unpublished reports specifically for Malawi. And this database has articles far dating back from colonial to present times. This is particularly a rich database for Malawi issues as it benefits from other worldwide databases that automatically feed to it or link to it any document with name Malawi or Nyasaland.

Unpublished Sources: Reports submitted by research scholars, universities and various educational and research institutions, committees and commissions appointed by government that regularly collect malaria entomological data such as CHAM hospitals, NGOs with vector control activities, and even commercial companies involved in malaria vector control made excellent data sources. Obtained data were also tabulated into a database with latitude and longitude, and vector identification included. All data were mapped using the Geographical Information Systems (GIS) programmes such as ArcGIS (ESRI, Redlands, CA) and QGIS. The overall studied areas and species distributions of the main *Anopheles* species were mapped.

## 3.0 Analysis Of Data From Reviewed Documents

The emergent data was analysed both qualitatively and quantitatively. The quantitative data was subjected to various quantitative analytical procedures. The analysis was Univariate using appropriate indicators as well as the application of more advanced statistical analysis (meta-analysis) if necessary. The analysis of the qualitative data utilised a logical chain of evidence.

## 4.0 Results

The reviewed documents presented in this paper are documented below. They include journal publications, technical reports, theses and book chapters.
Table 1 summarises sources of the reviewed documents.

**Table 1**: Sources of information used to compile the profile

| S/N | Source of data | Total |
|---|---|---|
| **1** | Technical Reports | 8 |
| **2** | Journal Articles | 60 |
| **3** | Theses | 2 |
| **4** | Book Chapters | 1 |

### 4.1 Malaria Vector Bionomics

A thorough knowledge of vector bionomics as an integral part of the epidemiological studies is indispensable for developing plans combining various methods of malaria vector control.

#### 4.1.1 Malaria Vectors

A total of thirteen reviewed articles reported on malaria vectors in Malawi. Of the thirteen, seven used Polymerase chain reaction (PCR) and the rest used morphology to identify Anopheline species. The available information indicate that the principal malaria transmitting vectors in Malawi are *Anopheles gambiae, An. arabiensis* and *An. funestus* (Tambala et al., 1992; Donnelly & Townson, 2000; Spiers et al, 2002; Pemba et al, 2009; Hunt et al, 2010; Mzilahowa et al., 2010; Wondji et al., 2012; Bennet et al., 2013; Riveron et al., 2013; Riveron et al., 2015; Mzilahowa et al., 2016). Available information indicate that the localized malaria vector species in Malawi include *An. rivulorum* (Riveron et al., 2013), and *An. funestus-like* (Vezenegho et al., 2013) (**Figure 1**). Other Anopheline species found in Malawi include: *Anopheles merus* (Mzilahowa et al, 2008), *An. parensis* (Riveron et al., 2015; Vezenegho et al., 2013), *An. Quardrianulatus, An. coustani, An. maculipalpis, An. pharoensis, An. pretoriensis, An. rufipes, An. sinerens, An. squamosus* and *An. ziemani* (Pemba, JICA Arbovirus Project, 2013).

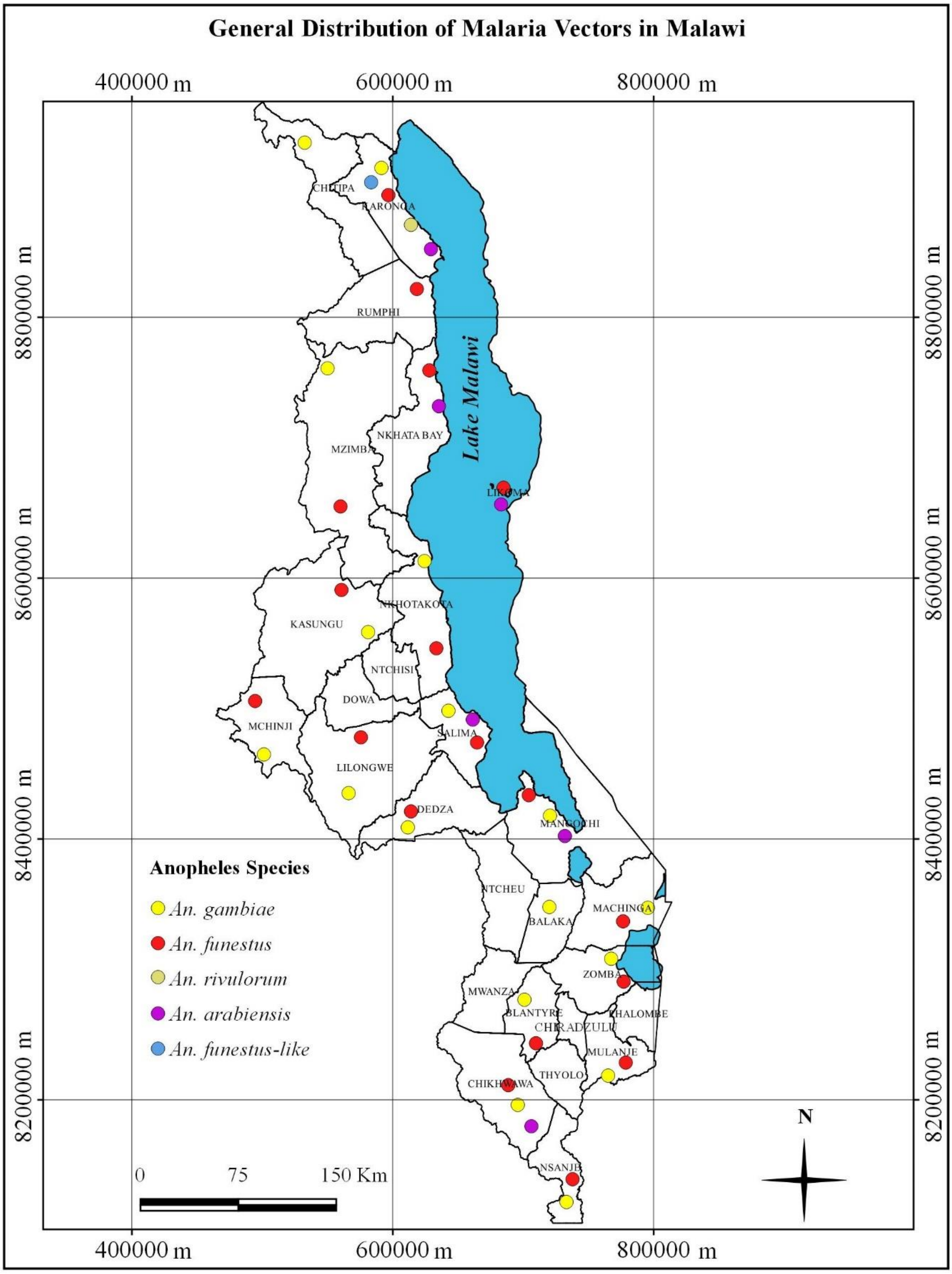



**Figure 1: General distribution of Malaria Vectors in Malawi**

### 4.1.2 Feeding and Resting Behaviour

Anopheline mosquitoes and other species, rely on their olfactory senses to locate a host following carbon dioxide cues (Webster, Lacey, & Cardé, 2015). Studies elucidating the biting behaviour of malaria vectors in Malawi are rare. Only six reviewed articles reported on feeding and resting behaviour of malaria vectors in Malawi. *Anopheles funestus* and *Anopheles gambiae* are the most efficient vectors of *Plasmodium falciparum* in Malawi (Spiers et al., 2002). Reviewed studies focused on indoor resting catches. Biting times and details on behavioural dynamics of exophilic anopheline are elusive. Studies by Gowelo (2016) among others, report the indoor resting and biting behaviour of *Anopheles funestus*, based on indoor catches. Similarly, Mzilahowa et al., (2012) in another study reported that *An. funestus* and *An. gambiae* are highly anthropophilic (expresses a tendency to feed on humans) as well as being endophagic (feeding indoors) and endophilic (resting indoors). *Anopheles arabiensis* a member of *An. gambiae* complex has been described as a zoophilic, exophagic and exophilic species. The species has been reported to readily feed on cattle, goats, chickens, dogs and other wild and domestic animals in its vicinity. Its feeding and resting patterns depend on geographical location (Gowelo, 2016). Most mosquito resting time is after, not before, a blood meal and they prefer to rest inside houses whilst their eggs develop (Chavasse, 2002). They seek out a quiet secluded place in the house (e.g. in the thatch, behind a curtain etc.) and wait until their eggs are mature. Gowelo, (2016) reported that *An. funestus* was more likely to bite indoors while *An. arabiensis* was more likely to bite outdoors. Furthermore, *An. funestus* has shown a biting peak in the morning from 4:00 am up to 6:00 am (Gowelo, 2016). Contrary findings were reported from elsewhere, *An. funestus* was reported to exhibit late night biting behaviour. Its late-night biting patterns potentially allows ready access to human blood without incurring undue density-dependent host avoidance (Malaria atlas project, 2017). The late-night biting preference is clearly evident throughout its range, with peak biting period generally occurring after 22:00, commonly between midnight and the early hours of the morning (Malaria atlas project, 2017). There is no reported study on *Anopheles gambiae* feeding and resting behaviour in Malawi. However, *Anopheles gambiae* has been reported to be less discriminant and more opportunistic in its host selection and that host choice is highly influenced by location, host availability and the genetic make-up of the mosquito population. Females of *An. gambiae* typically feed late at night and are often described as both endophagic and endophilic (Coluzzi et al., 1979).

Studies on anopheline biting behaviour in Malawi need to extend to the timing of the bites as well as details on outdoor biting behaviour of other anophelines.

### 4.1.3 Ecology

**S**ympatric occurrence of *An. funestus* and *An. gambiae* in Chikhwawa has been reported in Malawi and elsewhere (Kabula et al., 2011; Mzilahowa et al., 2012; Smita et al., 2016). The aquatic stage of both species wherever they existed were found in temporary or permanent puddles, borrow pits, irrigation ditches, vehicle ruts and rice paddies (Spiers et al., 2002). An exceedingly high transmission has been reported when both *An. funestus* and *An. gambiae* are present in a community (Pemba, 2015). This often occurs because these vector species exploit different breeding habitats and stagger their peak densities, which prolongs the transmission season

*Anopheles funestus* breeds in larval habitats that are somewhat different from those of the *An. gambiae* complex. *Anopheles funestus* prefers permanent collections of clean water with vegetation, such as marshes, ponds and the weedy edges of ditches or rice fields (Spiers et al., 2002). *Anopheles funestus* has been reported as a highly adaptable species, thus its able to occupy and maintain a wide distribution and utilize and conform to the many habitat types and climatic conditions (Malaria Atlas Project, 2017). It prefers more permanent breeding sites and its population tend to peak toward the end of the rainy season and into the first part of the dry season.

Members of the *An. gambiae* complex have been documented to adapt to different breeding sites with *An. gambiae s.s., An. arabiensis* and *An. quadriannulatus* preferring fresh-water breeding sites; *An. melas, An. merus* adapted to brackish water breeding and *An. bwambae* to mineral water *Anopheles arabiensis* favours arid zones while *An. gambiae s.s* favours humid areas (Lehmann & Diabate, 2008; Gowelo, 2016). *Anopheles gambiae* has shown a tendency to oviposit in temporary breeding sites such as puddles and animal foot prints, which are abundant during the rainy season (Smita et al., 2016).

### 4.1.4 Abundance And Seasonal Variability

A total of eleven articles were reviewed on abundance and seasonality, majority of the articles revealed the occurrence of *An. funestus* and *An. gambiae* in different areas across the country. The articles revealed predominance of *An. funestus* over *An. gambiae* with some deviations in number of catches at different times of the year in some areas.

Overall, *An. funestus* catches were high compared to *An. gambiae* across Malawi **(Figure 2)** (Pemba, JICA Arbovrus Project, 2013). Several studies have also reported a similar trend of high catches of *An. funestus* compared to *An. gambiae* in all the three regions of Malawi: In central region districts (Salima, Nkhotakota, Lilongwe) (Themba et al., 2014, Pemba, JICA Arbovrus Project, 2013), in the northern region districts (Likoma, Nkhatabay, Karonga) (Hunt et al., 2010; Vezenegho et al., 2013; Gowelo, 2016) and in the southern region districts (Machinga, Blantyre, Chikhwawa, Mangonchi) (Pemba et al, 2009; Mzilahowa et al., 2014; Lindblade et al., 2015; Mzilahowa et al., 2016). Contrary to these findings, Themba et al., (2012) reported a higher catches of *An. arabiensis* in Chikhwawa. Details of seasonal abundance of other malaria vectors in Malawi are lacking.

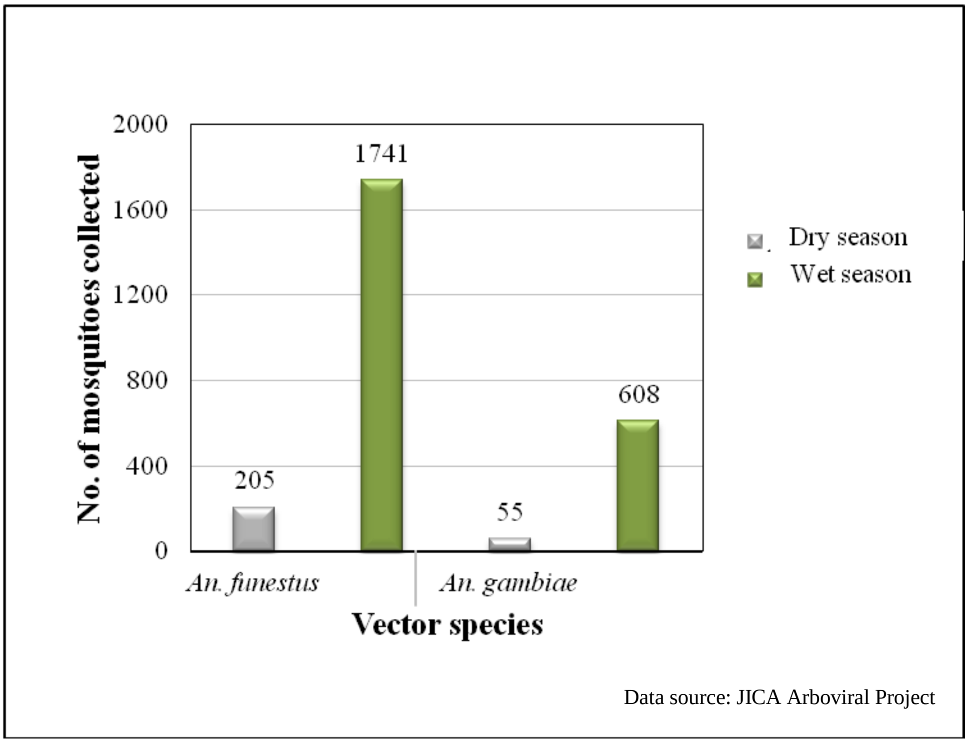
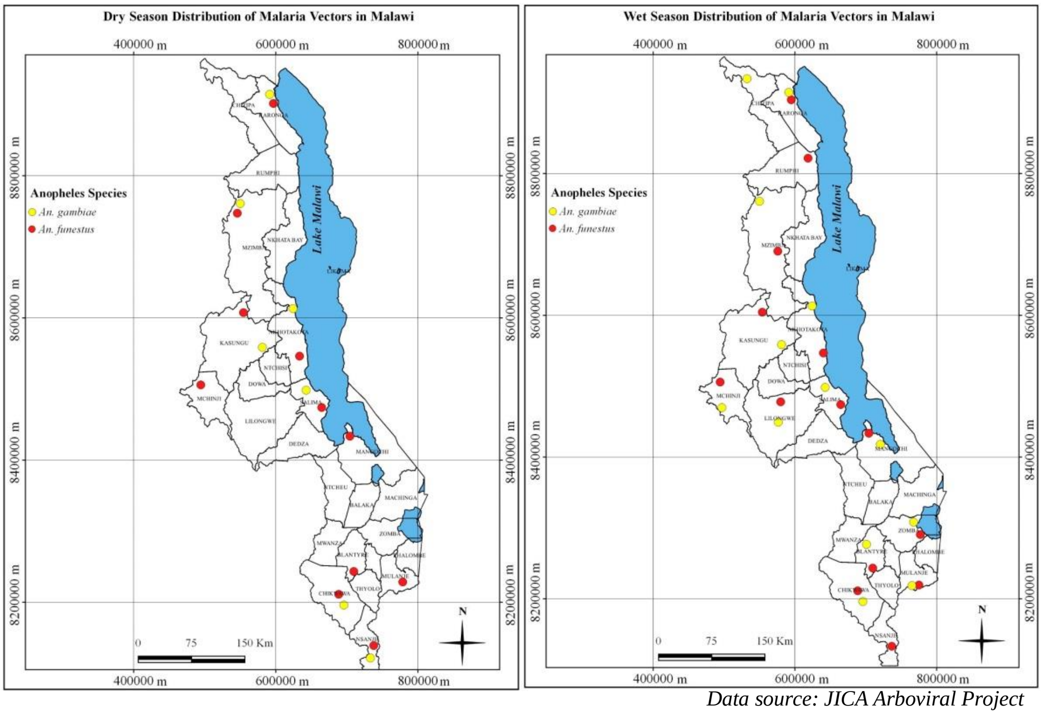



**Figure 2: Seasonal abundance of *An. funestus and An. gambiae* in Malawi**

The abundance of malaria vectors in Malawi varies with season. A similar trend was reported by Chanda et al., (2015). The number of mosquito catches was very high in wet season compared to dry season (Pemba, JICA Arbovrus Project, 2013) (**Figure 3)**. Several studies have also reported a similar trend; nonetheless, on average the *An. funestus* catches were higher than that of *An. gambiae* in both wet and dry seasons (Vezenegho et al., 2013; Pemba, 2015; Lindblade et al., 2015).




*Data source: JICA Arboviral Project*

**Figure 3: Seasonal Distribution of Malaria Vectors**

## 4.2 Malaria Transmission Intensity

Among the entomological studies conducted in the country, only four reported on malaria transmission intensity. Earliest studies on EIR were reported by Chiphwanya (unpublished). The study reported an EIR of 183 in Chikhwawa representing 15 bites per person per month. The reported sporozoite rates from PCR and ELISA analyses confirmed that a majority of the mosquito vectors carry *P. falciparium* except for *An. gambiae* which has been found to harbour *Plasmodium malariae* in some cases (Chiphwanya, unpublished). Recently, Gowelo (2016) reported a high infectivity in *An. funestus* a sporozoite rates of 3.6% in Nkhatabay, comparable to the sporozoite rates of 4% reported in Chikhwawa by Lindblade et al.,(2015). Sporozoite rate of 7% has also been reported in Nkhoma hospital catchment area (Lilongwe–Dedza) (Pemba, 2015).

Mosquitoes do not feed on human hosts only. They have a range of vertebrate hosts from which they derive their meals. Notably, *An. funestus* in Malawi has been reported to feed on other hosts such as cattle, pigs and dogs although in very small percentages compared to humans (Gowelo, 2016.). Similar observations have been reported by (Mzilahowa et al., 2012). Documented human blood indexes (HBI) in Malawi portray tendency of the vectors to feed more on humans than other hosts. Human blood index have been reported to exceed

92% in Chikhwawa (Mzilahowa et al., 2012), 41.6% in Nkhatabay and Karonga (Gowelo, 2016). The reported sporozoite rates in some parts of Malawi are shown in **Figure 4.** Districts with no plots of HBI and sporozoite rates do not imply risk free zones, country wide data on EIR, HBI and SR is lacking.

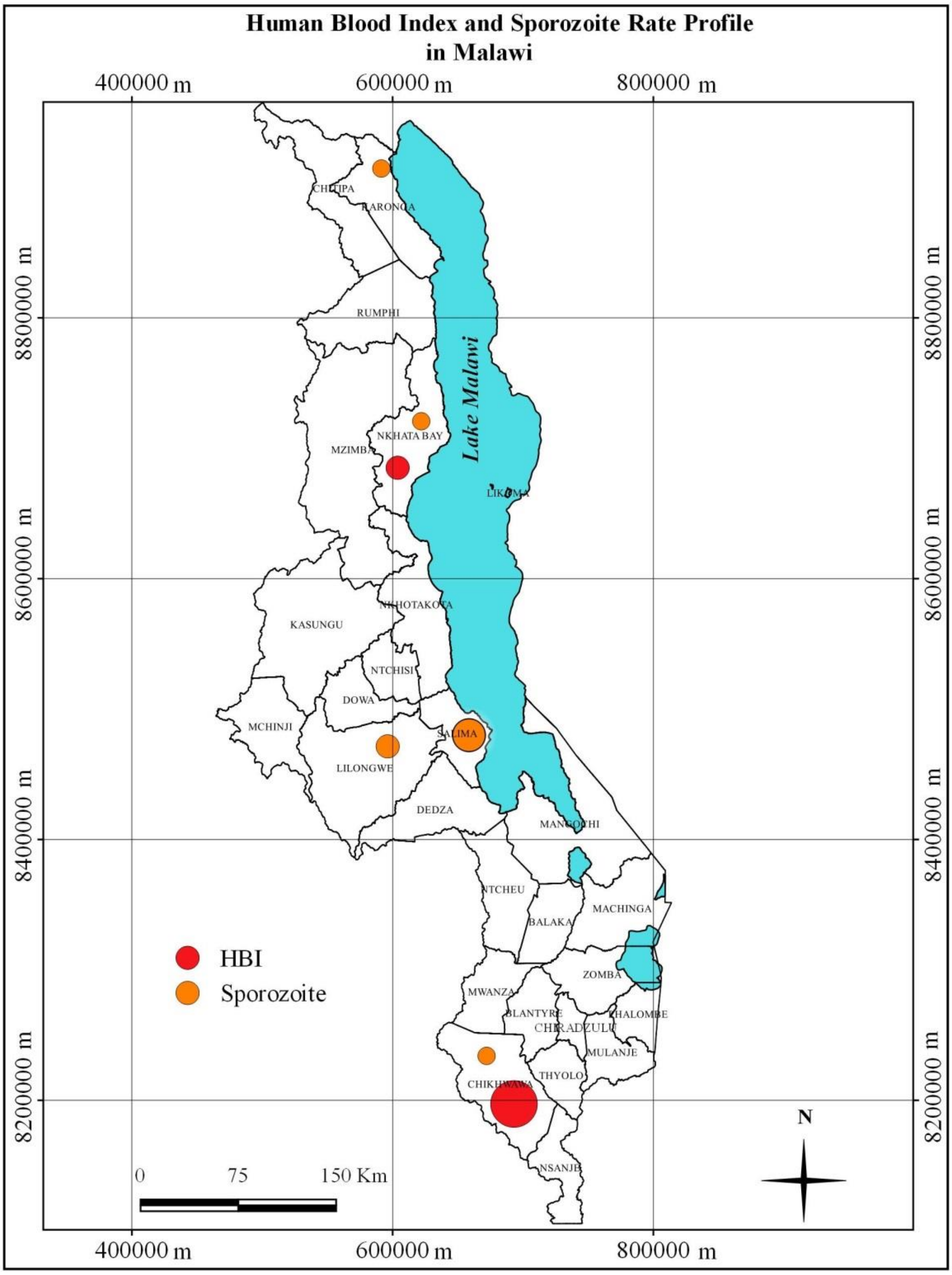
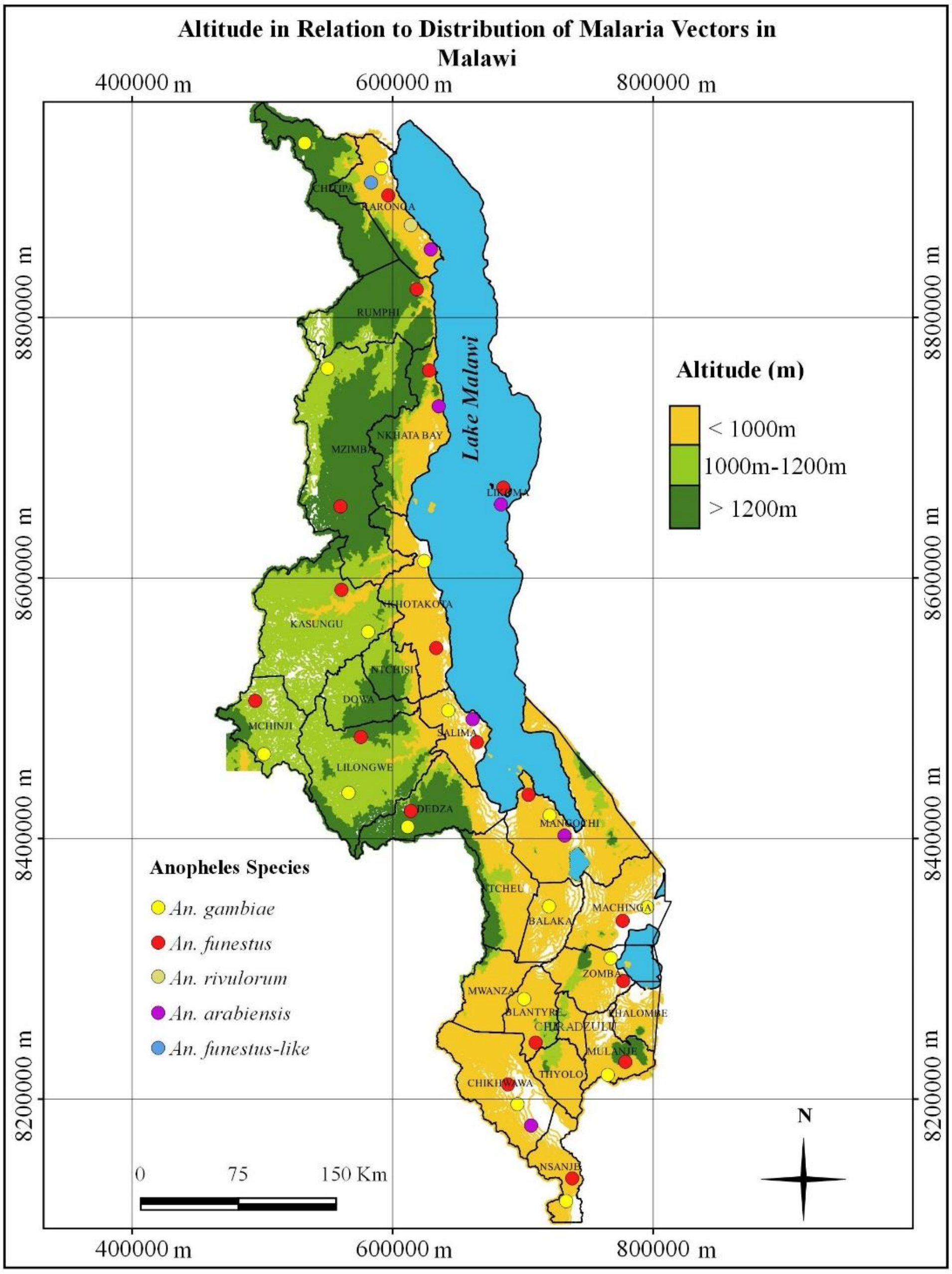



**Figure 4**: Sporozoites Rate and Human Blood Indices in some parts of Malawi

Environmental factors influence transmission intensities and sporozoite rates hence, influencing local transmission of malaria. High transmission has been reported in areas low lying areas that tend to have high temperatures during the rainy season (October – April) and along the low-lying areas, particularly the lakeshore and lowland areas of the Shire Valley (NMCP, 2011). Areas like Nkhotakota which lie at an elevation 472m above the sea level has a higher year round malaria transmission (Skarbinski et al., 2012)(**Figure 5** ). The lowest risk areas are found along the highland areas of Rumphi, Mzimba, Chitipa and Kirk Range (Kazembe, 2006, Kazembe et al.,2007). Similar observations have been reported by ( Rehman et al., 2011, Bennett et al., 2013, Pemba, 2015)

**Figure 5**: Malaria vectors distribution in relation to altitude

Note: Areas with altitude from 1000m-1200m have moderate transmission intensity and areas 1200m above sea level have low transmission intensity



## 4.3 Insecticide Resistance

There are four classes of insecticides used in malaria vector control in Malawi are[organochrorides, pyrethroids, organophosphates and carbamates] and biological agents. Mosquitoes become resistant behaviourally by avoiding exposure to lethal dose or physiologically by finding ways to survive a normally lethal dose to insecticides (Mullin and Scott, 1992). Behavioural mechanisms for resistance have been less studied than physiological (Sparks et al., 1989). Physiological resistance is divided into 3 mechanisms; reduced cuticular penetration, altered target site, increased metabolic detoxication or sequestration (Oppenoorth, 1985; Scott, 1991). Increased excretion is also a possible resistance mechanism though it has not convincingly been demonstrated (Mullin and Scott. 1992).

Multiple insecticide resistance mechanism may occur in the same mosquito population and this has been detected among major malaria vectors in Africa (WHO, 2012; Djouaka et al., 2016; Riveron et al., 2016). Multiple insecticide resistance mechanisms have been expressed in mosquitoes where a single mutation at a target site can result in mosquito resistance to DDT and pyrethroids or to organophosphates and carbamates (Perera et al., 2008). In *An. gambiae sl* mosquitoes, mutations in the sodium channel conferring DDT/pyrethroid Knockdown resistance (kdr) have been found in conjunction with resistance acetylcholinesterase gene alleles (Ace-1R), secondly the target site of organophosphates and carbamates (Yewhalaw et al., 2011). This multiple resistance poses a big challenge in malaria control programmes.

In Malawi, insect resistance has been detected from the principle malaria vectors; *An. funestus s.s*, *An. gambiae s.s.* and *An. arabiensis* **(Figure 6)**. Twenty-two studies reported on insecticide resistance of the major malaria vectors in different parts of Malawi. However, none of the studies reported on resistance across the whole country.

Malawi has extensively used four classes of insecticides; pyrethroids (used in nets and IRS), organophosphates (used in IRS), organochlorines and carbamates. Resistance has developed to some of these classes.

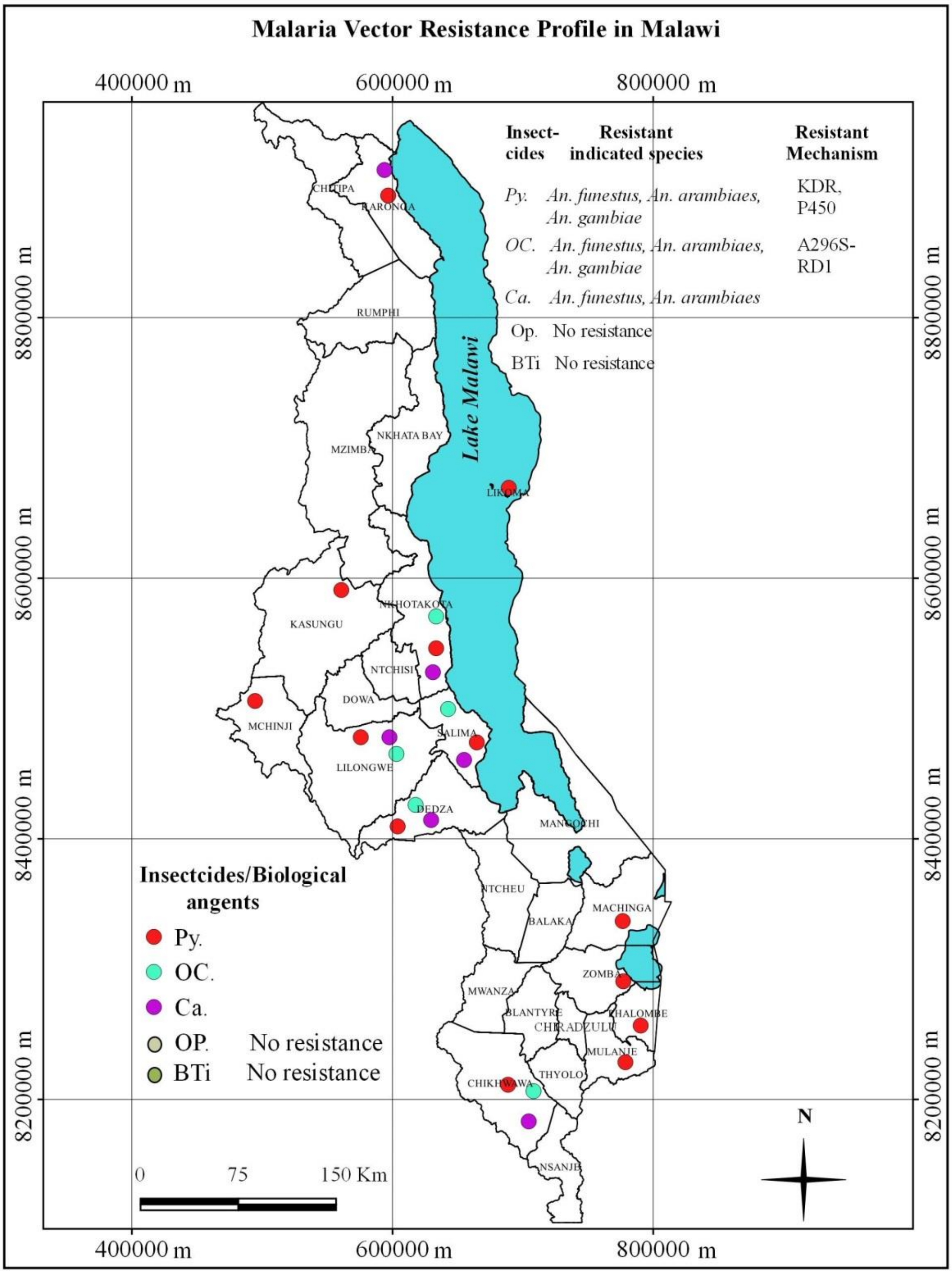



**Figure 6:** Insecticide resistance and mechanism across Malawi

According to most of the studies, *Anopheles funestus* exhibited high multiple resistance to insecticides across Malawi. In the three highly endemic areas of Chikhwawa, Salima and Nkhotakota, it showed high resistance to pyrethroids, carbamates and organochroline (Riveron et al., 2013; Mzilahowa et al., 2016; Barnes et al., 2017). Pyrethrod resistance has also been detected from this species in some parts of the central region of Malawi (Kasungu, Dedza, Lilongwe and Mchinji) and southern parts of Malawi (Phalombe and Zomba)

(NMCP, 2015; Pemba, 2016). Dieldrin resistance was detected in this vector in 2014 (Riveron et al., 2015).

Multiple insecticide resistance has been detected in *An. arabiensis* populations across Malawi. However, the resistance levels were slightly lower than those recorded in *An. funestus* populations. Pyrethroid and organochlorine resistance was detected in *An. arabiensis* population across Malawi between 2011 and 2015. A general decline trend in mortality was observed in *An. arabiensis* exposed to pyrethroids and carbamates over the years 2011-2015 (Riveron et al., 2015; Mzilahowa et al., 2016). *Anopheles arabiensis* population from the southern part of Malawi (Chikhwawa) showed moderate resistance when exposed to the organochlorine (Mzilahowa et al., 2008; Riveron et al., 2015).

Pyrethroid resistance was also detected in *An. gambiae s.s.* across Malawi. In general, the resistance levels for this species were lower than *An. funestus*. Pyrethroid resistance has been detected in *Anopheles gambiae s.s.* population from the southern part of Malawi (Chikhwawa) between 2009 and 2010 (Wondji et al., 2012) and from Liwonde town in Machinga district (Pemba and Namangale, 2009). Mosquitoes in Chitipa and some few selected parts of the country are still susceptible to pyrethroids.

The main mechanism driving pyrethroid resistance in the principle malaria vectors in Malawi is the over expression of cytochrome P450 genes (CYP6P9a, CYP6Pb and CYP6M7) (Lindblade et al., 2015; Barnes et al., 2017). A296S-RDl dieldrin resistance mutation is responsible for the dieldrin resistance (Riveron et al., 2015). Recently, Kdr mechanism has been reported in Nkhoma area (Pemba, 2015).

## 5.0 Biological Agents

Biological agents are commonly used in LSM. The biological agents are in two classes, bacterial based and growth hormones. In Malawi, the only one to have been used is bacterial based; *Bacillus thuringiensis israelensis* (BTI). This has been used in trials in Zomba, Chikhwawa and Mulanje districts. And so far no resistance has been reported (Pemba et al., 2013).

The rapid spread of multiple insecticide resistance in the principle malaria vectors in Malawi is of major concern and urgent resistance management strategies are needed in malaria vector control programmes. Pyrethroid resistance in the principle malaria vector populations across Malawi is of concern given that pyrethroids are the sole insecticide class currently recommended by the World Health Organization (WHO) for use in bed nets. The other alternatives to pyrethroids in IRS are expensive.

## 6.0 Recommendations Based On Malawi's Malaria Vector Profile

**a)** So far, 18 Anopheline species have been identified in Malawi. However the known transmitting species are about 4 namely; A*n. gambiae, An. funestus, An. arabiensis*, and *An. rivulorum*. As such where intervention is to be carried out, it is important to identify the local transmitters as the bionomics indicate varying behaviours among various vectors which if not taken into consideration may impact the outcome negatively.

**b)** Resistance has been observed in pyrethroids, carbamates, Organochlorine except in organophosphates and microbial larvicides. Pyrethroids are still effective in few selected areas. However, since pyrethroids are the only insecticide use in nets it is recommended that these chemicals should not be used in IRS at all to avoid further build up of resistance.

**c)** The three commonly used interventions on large scale are ITN, IRS and Larval Source Management. As of the current situation pyrethroids be restricted to ITNs, Organophosphates to IRS and microbial larvicides to LSM but such arrangements be monitored based on current information available.

**d)** There are a lot of gaps in information due to lack of comprehensive vector monitoring which must include; transmission indices, resistance and vector behaviour. There should be deliberate effort by NMCP to have national wide information on vector distribution, transmission indices, resistance and vector behaviour.

## 7.0 Limitations In Compilation Of This Entomological Profile

a) Considering that this was a 30 day work the methodologies focused mostly on data mining from existing information.

b) Lack of centralised information (database) on malaria vectors made the work so challenging.

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