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Indoor Residual Spraying (IRS 2) Task Order Six

# SENEGAL ENTOMOLOGICAL MONITORING REPORT

JULY 2015 – NOVEMBER 2015

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# SENEGAL ENTOMOLOGICAL MONITORING REPORT

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# ACRONYMS

| | |
|---|---|
| **AIRS** | Africa Indoor Residual Spraying Project |
| **CDC** | Center for Disease Control and Prevention |
| **DDT** | dichlorodiphenyltrichloroethane |
| **FST** | Faculty of Sciences and Technology |
| **HBR** | Human Biting Rate |
| **HLC** | Human Landing Catch |
| **IRD** | Indoor Resting Densities |
| **IRS** | Indoor Residual Spraying |
| **kdr** | knockdown rate |
| **LEVP** | Laboratory of Vector and Parasite Ecology |
| **LLINs** | Long-Lasting Insecticide Treated Nets |
| **NMCP** | National Malaria Control Program |
| **PCR** | Polymerase Chain Reaction |
| **PHN** | Per Human Night |
| **PMI** | Presidential Malaria Initiative |
| **PR** | Parity Rate |
| **PSC** | Pyrethrum Spray Catch |
| **VC** | Vector Control |
| **VFS** | Senegal River Valley |
| **UCAD** | University Cheikh Anta Diop |
| **USAID** | United States Agency for International Development |
| **WG** | Wettable granules |
| **WHO** | World Health Organization |

# EXECUTIVE SUMMARY

The residual efficacy of indoor residual spraying (IRS) with pirimiphos-methyl (Actellic CS 300) using a susceptible strain of *Anopheles gambiae* (*Yaounde/"Boudin"*) was monitored for six months after spraying. IRS remained effective (providing >80% mortality in cone bioassay) for five months in the districts of Koungheul, Koumpentoum, and Malem Hodar, with similar levels of mortality on treated mud and cement walls. However, the residual duration of Actellic CS was shorter in Nioro District and lasted just two months. Also in Nioro District, houses in Ndramé Ndimb were sprayed with bendiocarb (Ficam WG 10%), but the residual efficacy was even shorter, with mortality >80% for only one month. There were no substantial variations in the efficacy of either insecticide according to the type of wall substrate (mud or cement). It is important to investigate the reasons for the particularly short residual duration of both bendiocarb and pirimiphos-methyl in Nioro and determine whether spray operators require re-training. Due to the decrease in efficacy six months after spraying the start of the IRS campaign could be moved to July, to cover the entire transmission period of July to November.

World Health Organization (WHO) susceptibility tests indicated that *An. gambiae* s.l. remain fully susceptible to pirimiphos-methyl, except in Koungheul where initial signs of resistance were recorded. This should be investigated further in 2016. Malaria vectors were also susceptible to bendiocarb in most places except in Ndoffane and Niayes where low-level resistance was recorded. Higher frequency bendiocarb resistance was observed in the suburbs of Dakar where pesticides are used for small scale agriculture (market gardening). Resistance to pyrethroids and dichlorodiphenyltrichloroethane (DDT) was widespread and appeared to be at similar frequencies for all types of pyrethroid.

Entomological surveillance was conducted within sprayed 'hot spots', which were selected to be sprayed based on malaria epidemiology data. Entomology monitoring was also conducted in unsprayed 'internal controls' from within the IRS districts. In addition several unsprayed districts that do not neighbor IRS districts were included in order to get a geographical representation of Northern, Central and Southern Senegal.. Entomology surveillance showed that in all monitored IRS districts the predominant vector species complex was *Anopheles gambiae* s.l., while in Nioro *An. funestus* s.l. were also frequently collected. In IRS districts the human biting rate (HBR) of *An. gambiae* s.l. was generally very low, at between 0.5 and 1.2 bites/person/night. This may be an indication that IRS was successful in reducing the malaria vector population size. However, the HBR in internal and external control villages (unsprayed) was also very low. In all unsprayed control villages (internal and external) the HBR was less than 2 bites per night. In unsprayed southern districts the predominant vector species complex present was also *An. gambiae* s.l. Of particular concern were the high indoor biting rates in the districts of Velingara, Kédougou, and Tambacounda, which reached peak rates of 36, 65, and 81 bites per person/night, respectively. In the same districts there was a similar amount of indoor and outdoor biting risk; however, the level of outdoor exposure will depend on local cultural night time practices.

Indoor resting densities (IRD) were very low in treated villages with a mean of between 1.3-2.4 *An. gambiae* s.l. per house/night. The mean resting densities in internal control villages were greater at between 1.9-8.7 females/house/night. The biting rates and indoor resting catches were similar, indicating predominantly endophilic tendencies in this area. Southern districts (Tambacounda, Kedougou and Velingara) had the highest indoor biting rates but indoor resting densities were relatively low. For example, in Tambacounda the mean pyrethrum spray catch (PSC) was only 5.4 *An. gambiae* s.l. per house in October, despite an indoor HBR of 81 bites per person/night. This suggests that blood-fed *An. gambiae* s.l. exited before dawn in southern districts. In the districts of the Senegal River Valley (Central and North Senegal), the indoor HBR was less than 5 bites per night and there was a trend of endophily.

In Ranérou (unsprayed) the indoor HBR was 3.3 but mean PSC catch was 9.6 *An. gambiae* s.l. per house/night. This appears to indicate different resting behavioral characteristics by region.

The longevity of *Anopheles gambiae* s.l. females in terms of parity status was determined for sprayed villages as well as internal and external unsprayed controls. The proportion of parous *An. gambiae* s.l. appeared to be similar in sprayed and internal control areas (although numbers dissected in some districts were small). Parity rates were generally high (above 50%) and had classic dynamics with lower parous rates during periods of high population density and higher rates with aging populations toward the end of the rainy season.

The low biting rates and indoor resting densities in IRS sites appear to be indicative of a successful spray campaign. However, it should be noted that in many internal and external control sites (unsprayed) the biting rates were also very low and further investigation is needed to determine whether IRS is a cost-effective strategy in areas currently being sprayed. The very high indoor and outdoor biting rates of *An. gambiae* s.l. in non-IRS sites in southern districts of Velingara, Kédougou, and Tambacounda need to be investigated further to determine whether they constitute important areas of malaria transmission and whether additional control measures are needed. The exophilic behavior of *An. gambiae* s.l. in southern areas (as inferred from high indoor biting rates with low PSC resting densities) should also be studied further before any additional indoor interventions are considered.

Laboratory analysis for species identification, frequency of knockdown rate (kdr) and sporozoite rates is currently ongoing. We report species identification only for Kedougou, Dakar suburbs (Pikine & Guédiawaye), and Niayes in the current report, and sporozoite rates, *kdr*, and blood meal analysis for Niayes.

# 1. INTRODUCTION

As part of the President's Malaria Initiative (PMI), the U.S. Agency for International Development (USAID) provides technical and financial support to the National Malaria Control Program (NMCP) of Senegal and has introduced indoor residual spraying (IRS) of residual insecticide since June 2007 in selected districts. In Senegal, IRS implementation began as a pilot in three health districts (Vélingara, Nioro, and Richard-Toll) in 2007. Based on the results achieved, NMCP and PMI decided to expand IRS to three new districts (Guinguinéo, Malem Hodar, and Koumpentoum) in 2010. Given the relatively low incidence of malaria in the Senegal River Valley (VFS), particularly in the Delta, NMCP and PMI decided to stop IRS activity in these areas, deciding instead to implement IRS in a new district (Koungheul) in 2011. The NMCP has since adopted a targeted approach for IRS: a) districts with a yearly incidence of less than 30 per 1,000 will not receive IRS; b) districts with an incidence between 30 and 50 per 1,000 may have targeted IRS in the health post zones where malaria incidence is greater than 50 per 1,000 (hot spots); and c) districts with an incidence greater than 50 per 1,000 will receive IRS over the whole district.

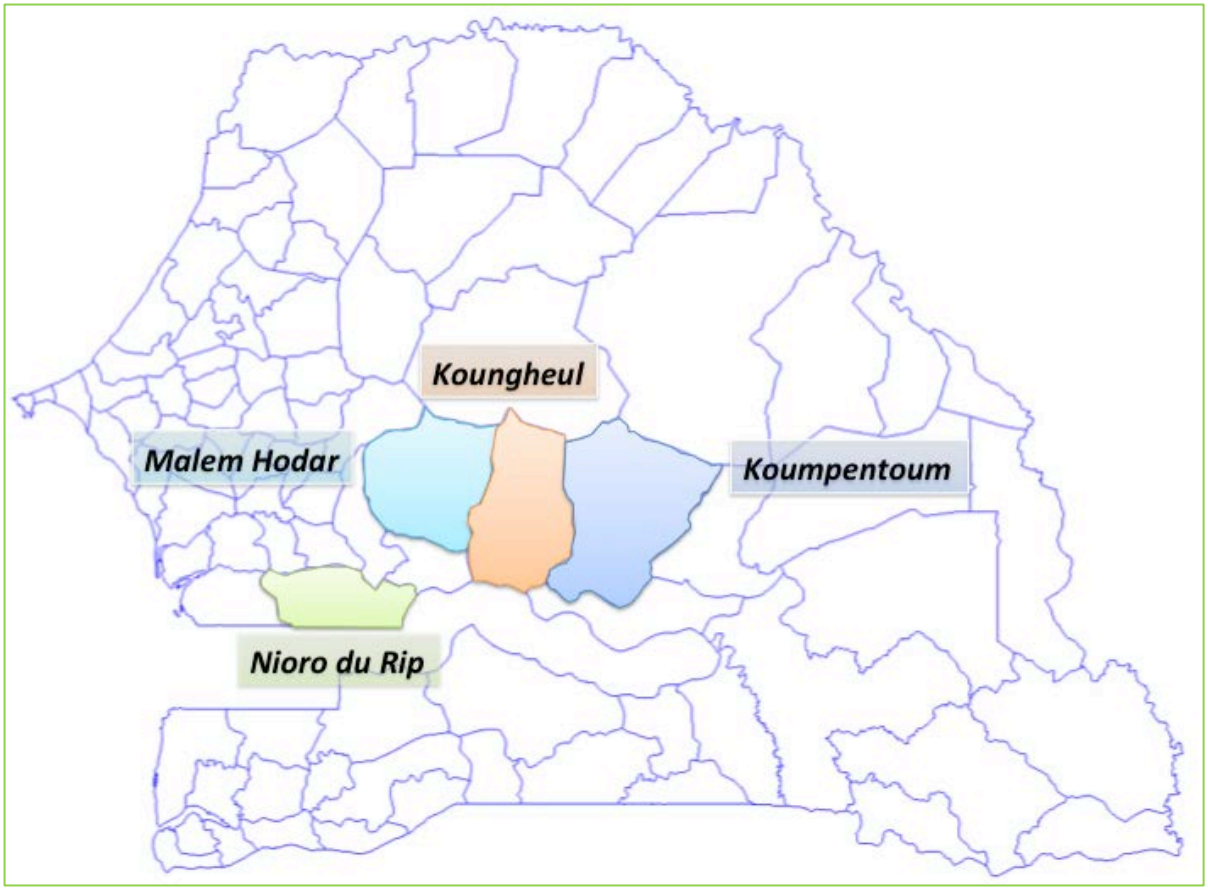
**Table X. IRS coverage in Senegal through PMI from 2012 to 2017**

| Year | Number of Districts Sprayed | Insecticide Used (# districts) | Number of Structures Sprayed | Coverage Rate | Population Protected |
|---|---|---|---|---|---|
| 2012 | 6 | Bendiocarb | 306,916 | 98% | 1,095,093 |
| 2013 | 4 | Bendiocarb | 206,704 | 98% | 690,090 |
| 2014 | 4 | Bendiocarb (2)<br>Organophosphate (2) | 204,159 | 97% | 708,999 |
| 2015 | 4 (hot spots) | Bendiocarb (1)<br>Organophosphate (3) | 130,170 | 97.7% | 514,833* |
| 2016 | 4 (hot spots) | Organophosphate | 90,000** | TBD | 300,000** |
| 2017 | TBD (hotspots) | Organophosphate | 75,000** | TBD | 250,000** |

**Preliminary data as of August 2015; **Represents projected targets*

The Laboratory of Vector and Parasite Ecology (LEVP) of the Faculty of Science and Technology (FST) at the University Cheikh Anta Diop (UCAD) in Dakar was responsible for the entomological assessment of the effectiveness of IRS in the target districts as part of its collaboration with the NMCP. The main results of the rainy season ('winter' period July-November) of the 2015 campaign are presented in this report.

**Figure 1. Geographical locations of the PMI-Senegal IRS districts sprayed for the 2015 campaign**




**Spray rounds and Survey dates for each IRS sentinels sites during the 2015 campaign**

| Districts | Sentinels Sites | Products | Spray rounds | 1st survey | 2nd survey | 3rd survey | 4th survey | 5th survey |
|---|---|---|---|---|---|---|---|---|
| **Koungheul** | Pakala | Actellic | 08 June | 02/08 | 25/08 | 14/09 | 15/10 | 19/11 |
| | Ida Mouride | Actellic | 13 June | 01/08 | 23/08 | 12/09 | 14/10 | 20/11 |
| | Touba Koungheul* | Actellic | 08 June | 01/08 | - | - | - | - |
| **Malem Hodar** | Makka Bella | Actellic | 23 May | 30/07 | 22/08 | 18/09 | 05/10 | 26/11 |
| | Tip Saloum | Actellic | 02 June | 30/07 | 25/08 | 17/09 | 07/10 | 28/11 |
| | Touba Gueyene* | Actellic | 26 May | 31/07 | - | - | - | - |
| **Koumpentoum** | Haltou Fass* | Actellic | 07 June | 03/08 | - | - | - | - |
| | Village 1 | Actellic | 29 May | 04/08 | 22/08 | 13/09 | 16/10 | 27/11 |
| | Koumare | Actellic | 05 June | 03/08 | 22/08 | 12/09 | 18/10 | 22/11 |
| **Nioro** | Bamba Diakhatou | Actellic | 01 June | 31/07 | 28/08 | 28/09 | 30/10 | 19/11 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Thiamene Walo** | Actellic | 27 May | 30/07 | 30/08 | 30/09 | 03/11 | 22/11- |
| | ***Ndrame Ndimb*** | ***FICAM*** | ***14 Sept*** | ***29/09*** | ***31/10*** | ***19/11*** | ***01/11*** | ***21/11*** |

*Sites ruled out after one month of monitoring

**Replaced by the village of **Paos Koto** after the 1st survey

# 2. METHODOLOGY

## 2.1 DISTRICTS AND SENTINEL VILLAGES FOR THE 2015 CAMPAIGN

Table 1 presents the sentinel villages, including unsprayed internal and external controls, selected for IRS districts that were followed during the 2015 IRS campaign. Fifteen (15) sentinel sites were selected based on stratification of villages by their malaria transmission level (i.e. 'hot spots'), geographical representation, and existence of a health post. Entomological monitoring of hot spots, unsprayed 'internal controls' from within the IRS districts and neighboring unsprayed 'external controls' were conducted. In addition several unsprayed districts that do not neighbor IRS districts were included in order to get a geographical representation of Northern, Central and Southern Senegal.

Thus, in each of the four IRS districts, three sentinel sites are selected: two from malaria hotspot villages (health posts that received IRS in 2015) and one from a non-hot spot (health post that did not receive IRS in 2015. There were three external control sites because the one for Kaffrine was the control for Malem Hodar and Koungheul.

Data were collected from July to November 2015 to monitor the sentinel sites after the spraying campaign, which took place from May the 23th to September the 14th 2015. Data were collected from both the IRS districts (including internal control sites) and non-IRS districts (including external sites) listed in Tables I and II, respectively. The geographical locations of the IRS districts are shown in the Figure 1.

**TABLE 1: SENTINEL VILLAGES SELECTED IN THE IRS DISTRICTS, JUNE 2015-MARCH 2016**

| Years since spraying began | Health district | Sentinel villages | External controls |
|---|---|---|---|
| 5 | Koumpentoum | Koumaré, Village I and Kouthiaba* | Koussanar (Tambacounda) |
| 5 | Malem Hodar | Makka Bella, Tip Saloum and Diankhé Souf* | Pété (Kaffrine) |
| 4 | Koungheul | Pakala, Ida Mouride and Keur Sérigne Diabel* | |
| I | Nioro | Bamba Diakhatou, Ndramé Ndimb and Paos Koto. | Keur Socé (Ndoffane) |

*Internal Controls

**TABLE 2: SENTINEL VILLAGES SELECTED IN UNSPRAYED DISTRICTS**

| Health district | Sentinel villages | Entomological activities |
|---|---|---|
| **Northern and East Central Districts** | | |
| Niayes | Ngadiaga, Ndiambalo, Thiaye, Touba Taw Fekh & Beer | HLC indoors/outdoors, indoor PSC, parity rates, susceptibility tests. |
| Richard-Toll | Mbagame, Polo, Ndiandiou, Maka Diama, Taba Darou Salam, Malé, Gnith, Ronkh, Khor & Reynabé I | Indoor PSC, susceptibility testing. |
| Linguère | Barkédji & Ouarkhokh | HLC indoors/outdoors, indoor PSC, parity rates. |
| Podor | Ndiayène Pendao & Niandane | HLC indoors/outdoors, indoor PSC, parity rates. |
| Ranérou | Oudalaye & Fourdou | HLC indoors/outdoors, indoor PSC, parity rates. |
| Matam | Sadel & Nabadji Ciwol | HLC indoors/outdoors, indoor PSC, parity rates. |
| Kanel | Haouré & Dembankané | HLC indoors/outdoors, indoor PSC, parity rates. |
| Bakel | Gabou & Moudéry | HLC indoors/outdoors, indoor PSC, parity rates. |
| Fatick | Fatick | Suceptibility testing. |
| Mbour | Mbour-Thies. | Suceptibility testing. |
| Niakhar | Niakhar | Susceptibility testing. |
| Bambey | Bambey-Diourbel | Suceptibility testing. |
| Pikine et Guédiawaye | (Flooded areas in suburbs of Dakar) | Susceptibility testing. |
| **Southern Districts** | | |
| Vélingara | Madina Dianguet & Nemataba | HLC indoors/outdoors, indoor PSC, parity rates, susceptibility tests. |
| Tambacounda | Wassadou, Badi-Gnongani Niériko & Koussanar | HLC indoors/outdoors, indoor PSC, parity rates. |
| Kédougou | Tomboronkoto & Bandafassi | HLC indoors/outdoors, indoor PSC, parity rates, Susceptibility testing. |
| Guinguinéo | Farabougou & Ngathie Naoudé | Susceptibility testing. |
| Ndoffane | Keur Socé | HLC indoors/outdoors, indoor PSC, parity |
| Kaffrine | Pété | HLC indoors/outdoors, indoor PSC, parity |

## 2.2 ACTIVITIES CARRIED OUT

Entomological monitoring activities focused on:

**Monitoring the effectiveness of IRS treatment**

- Nioro, Koungheul, Koumpentoum, Malam Hodar

Frequency = monthly until mortality <80%, n = 360 *An. gambiae* s.s. per site.

**Monitoring human biting rates (HLC indoors and outdoors)**

- IRS areas: Nioro, Koungheul, Koumpentoum, Malem Hodar

Frequency = 18 human nights sampled per month for 6 months per district.

- External control districts: Ndoffane, Kaffrine, Tambacounda

Frequency = 06 human nights sampled per month for 6 months per district.

- Unsprayed districts: Niayes, Linguere, Podor, Ranerou, Matam, Kenel, Bakel, Velingara, Tambacounda, Kedougou.

Frequency = 12 human nights sampled in August and October (2 months).

**Mosquito resting densities (indoor PSC)**

- IRS areas: Nioro, Koungheul, Koumpentoum, Malam Hodar

Frequency = 30 rooms sampled per month for 6 months.

- Unsprayed districts: Niayes, Linguere, Podor, Ranerou, Matam, Kenel, Bakel, Velingara, Tambacounda, Kedougou.

Frequency = 20 rooms sampled for only 2 non-consecutive months (e.g. August, October).

**Mosquito parity rates**

- IRS areas: Nioro, Koungheul, Koumpentoum, Malam Hodar
- Unsprayed districts: Niayes, Linguere, Podor, Ranerou, Matam, Kenel, Bakel, Velingara, Tambacounda, Kedougou.

Frequency = Undefined proportion of *An. gambiae* s.l. from HLC.

**Mosquito susceptibility to insecticides**

- IRS areas: Nioro, Koungheul, Koumpentoum, Malam Hodar
- Unsprayed districts: Fatick, Bambey, Niakhar, Mbour, Pikine & Guediawaye, Guinguineo, Ndoffane.

## 2.3 EFFECTIVENESS OF INDOOR RESIDUAL SPRAYING

Treatment effectiveness in IRS districts was determined each time in 12 residential rooms chosen in two treated villages, with six rooms tested per village (five rooms treated and one untreated control room). In each village, tests were performed in five houses in one room per house. The choice of rooms in the villages was done by lottery and selected rooms were repeatedly tested each month during monitoring.

Cone bioassays were performed in each room according to WHO standard protocols. Female mosquitoes of a susceptible strain of *Anopheles coluzzii* maintained at the insectary (Research Institute for Development, Institut Pasteur of Dakar, and Parasite Vector Control Service) were used for this purpose. For the tests, three cones were placed on each wall and 10 mosquitoes were exposed in each

cone. The location of the cones on the walls changed slightly each month as it was noted that tape used for attaching cones removed part of the wall surface when removed. For the negative controls four cones were fixed to a piece of untreated white paper and then attached to an untreated wall. Mortality of test mosquitoes was recorded 24 hours after exposure, with Abbott's correction implemented if mortality was between 5 and 20% in the negative controls. The IRS treatment was considered effective if the mortality was greater than 80%, as described by WHO.

**TABLE 3: IRS TREATMENT DATES AND TIMING OF CONE BIOASSAY IN THE IRS SENTINEL VILLAGES IN 2015**

| District | Sentinel site | IRS product | Treatment date | 1st test | 2nd test | 3rd test | 4th test | 5th test | 6th test |
|---|---|---|---|---|---|---|---|---|---|
| Koungheul | Pakala | Actellic | 08 June | 02/08 | 25/08 | 14/09 | 15/10 | 19/11 | 20/12 |
| | Ida Mouride | Actellic | 13 June | 01/08 | 23/08 | 12/09 | 14/10 | 20/11 | 17/12 |
| | Touba Koungheul* | Actellic | 08 June | 01/08 | | | | | - |
| Malem Hodar | Makka Bella | Actellic | 23 May | 30/07 | 22/08 | 18/09 | 05/10 | 26/11 | - |
| | Tip Saloum | Actellic | 02 June | 30/07 | 25/08 | 17/09 | 07/10 | 28/11 | - |
| | Touba Guéyène* | Actellic | 26 May | 31/07 | | | | | - |
| Koumpentoum | Haltou Fass* | Actellic | 07 June | 03/08 | | | | | - |
| | Village I | Actellic | 29 May | 04/08 | 22/08 | 13/09 | 16/10 | 27/11 | 29/12 |
| | Koumaré | Actellic | 05 June | 03/08 | 22/08 | 12/09 | 18/10 | 22/11 | 30/12 |
| Nioro | Bamba Diakhatou | Actellic | 01 June | 31/07 | 28/08 | 28/09 | 30/10 | 19/11 | 30/12 |
| | Ndramé Ndimb | FICAM | 14 Sept | 29/09 | 31/10 | 19/11 | 01/11 | 21/11 | - |
| | Thiaméne Walo** | Actellic | 27 May | 30/07 | 30/08 | 30/09 | 03/11 | 22/11 | - |

*Villages out of the study after one-month follow up.

**Replacement for Paos Koto

## 2.4 MONITORING VECTOR DYNAMICS

Sampling of vector populations was made by i) indoor collections in homes by pyrethrum spray catch (PSC) and ii) night time human landing catches (HLC) indoors and outdoors.

Collections of indoor resting mosquitoes by PSC were done early in the morning and were performed in all treated villages and controls in 10 rooms per village during one day each month. HLC was conducted overnight in selected villages in the districts treated and those untreated (except Richard-Toll). In every village HLC was carried out for two consecutive nights in three houses for a total of 6 human/nights outdoors and 6 human/nights indoors. The collected specimens were morphologically identified (genus/species) and counted in the field. A subsample of human biting females was dissected to determine the parity rate. Blood-meal samples were taken from females on Whatman filter papers for the determination of blood meal source. The captured females were individually stored in micro-tubes for laboratory analyses (sporozoite and kdr gene detection).

## 2.5 INSECTICIDES SPRAYED

In this indoor residual spraying campaign, in the districts concerned, the village health posts were sprayed where the previous year malaria incidence was greater than 15 cases per 1000 inhabitants. Pirimiphos-methyl (Actellic CS 300) was sprayed at 1g/m² in the districts of Koungheul, Koumpentoum, Malem Hodar, and Nioro. The Thilagran health post (Nioro) was the only one sprayed with bendiocarb (Ficam WG 10%); processing and testing dates are shown in Table 3.

## 2.6 WHO SUSCEPTIBILITY TESTS

Insecticide susceptibility tests were carried out in four sprayed districts and in selected unsprayed districts. Adult females of 2-5 days old that were collected from the wild as larvae were used for testing.

**Insecticides tested**

The tests were carried out in WHO-test cylinders with papers impregnated with diagnostic concentrations of the following insecticides:

**Pyrethroids:**

- Deltamethrin 0.05%
- Lambda-cyhalothrin 0.05 %
- Permethrin 0.75%
- Cyfluthrin 0.15%
- Alpha-cypermethrin 0.1%

**Organochlorines:**

- DDT 4 %
- Dieldrin 4%

**Organophosphates:**

- Malathion 5 %
- Fenitrothion 1%
- Pirimiphos-Methyl 1%

**Carbamates**:

- Bendiocarb 0.1 %

Mosquitoes were exposed to treated papers for one hour and mortality was recorded after 24 hours post exposure.

For each insecticide, at least 100 mosquitoes were tested in four replicates of 25. An accompanying negative control was always tested. The basis of the interpretation of the results is presented in the table below based on WHO 2013 guidelines.

| **Susceptibility status** | **WHO threshold** | **Additional threshold** | **Observations** |
|---|---|---|---|
| Susceptible | 98-100% | 98-100% | Susceptibility confirmed |
| Resistant | Less than 98% | 90-98% | Resistance suspected |
| | | Less than 90% | Resistance confirmed |

## 2.7 CDC BOTTLE BIOASSAYS FOR RESISTANCE MONITORING

The insecticide susceptibility tests were carried out in the four IRS districts (Koungheul, Koumpentoum, Malem Hodar, and Nioro) and in six untreated districts: Kédougou, Guinguinéo, Richard Toll, Rufisque, and Dakar suburbs (Pikine and Guediawaye). Female *An. gambiae* s.l. from wild larvae that were 2- to 5-days-old were used for these tests.

The specimens were exposed to the diagnostic time of 30 minutes (45 minutes for DDT) and the tests were corrected with Abbott's formula control with mortality between 3 and 10%. The interpretation of the results is based on WHO criteria for susceptibly tests.

## 2.8 LAB MOLECULAR ANALYSES

From *An. gambie s.l.* collected by HLC, infective females detection was made by the method of Enzyme-Linked Immuno-Sorbent Assay circumsporozoite (CSP ELISA) described by Burkot et al., (1984) and slightly modified by Wirtz et al., (1987).

From *An. gambie s.l.* collected by PSC, the origin of blood meals was determined by the direct ELISA method described by Beier et al. (1986).

The molecular identification of *An. gambiae* sibling species was performed on a subsample of living and dead female from susceptibly tests. The molecular identification was performed by PCR according to the protocol of Wilkins et al. (2006).

# 3. RESULTS

## 3.1 RESIDUAL EFFECTIVENESS OF INSECTICIDE SPRAYING AGAINST A SUSCEPTIBLE STRAIN OF *ANOPHELES GAMBIAE* S.S. IN CONE BIOASSAY

The residual performance of IRS was determined by monthly cone bioassay with a laboratory strain of *An. gambiae* s.s. for sixth months after spraying. Treatment with pirimiphos-methyl (Actellic CS 300) remained effective for five months in the districts of Koungheul, Koumpentoum, and Malem Hodar but only two months in Nioro District. In the village of Ndramé Ndimb in Nioro District bendiocarb (Ficam WG 10%) was effective for less than one month (Table 4).

**TABLE 4: RESIDUAL PERFORMANCE OF IRS AGAINST A SUSCEPTIBLE STRAIN OF *AN. GAMBIAE* S.S. DURING THE RAINY SEASON OF JUNE-NOVEMBER 2015**

| Districts | | Mortality: % (dead/total tested) | | | | | |
|---|---|---|---|---|---|---|---|
| | | < 1 month June | 2 month July | 3 months August | 4 months September | 5 months October | 6 months November |
| Koumpentoum¥ | Control | - | 1.9% (2/106) | 6.25% (5/80) | 1.2 % (1/83) | 11.9 % (10/84) | 2.5 % (2/81) |
| | Test | - | 100% (284/284) | 96.8%* (291/300) | 87.2% (246/282) | 85%* (204/235) | 67.2 % (195/290) |
| Koungheul¥ | Control | - | 2.4% (3/123) | 2.5% (2/80) | 1.25% (1/80) | 1.4 % (1/71) | 0 % (0/80) |
| | Test | - | 100% (353/353) | 100% (300/300) | 97.7% (293/300) | 89.4% (262/293) | 52 % (133/256) |
| Malem Hodar¥ | Control | - | 6.7% (9/135) | 0% (0/81) | 7.2% (6/83) | 10% (4/40) | 1% (1/80) |
| | Test | - | 95.2%* (445/466) | 99% (314/317) | 17.7*% (70/296) | 82.6*% (129/150) | 17.9% (54/302) |
| Nioro¥ (Actellic CS)¥ | Control | - | 0% (0/80) | 2.2% (1/45) | 5.5% (4/72) | 2,5% (1/40) | 3.3% (1/30) |
| | Test | - | 100% (300/300) | 42.6% (63/148) | 72*% (181/246) | 53.5% (84/157) | 31.9% (29/91) |
| Nioro (FICAM)£ | Control | 2.3% (1/43) | 2.5% (1/40) | 0% (0/32) | - | - | - |
| | Test | 95.2% (140/147) | 31.4% (49/156) | 14.4% (13/90) | - | - | - |

*corrected mortality;
Nioro (Actellic)¥ : Bamba Diakhatou, and Thiamène Walo (the latter village was removed from the study 2 months after follow up). Nioro (FICAM)£ : Ndramé Ndimb (village treated in September).

There are different teams covering several districts. The same entomology team covered Nioro and Malem Hodar where strange decreases in mortality were recorded. It was subsequently found that some technicians in this team were wiping the wall surface clean before they attached cones.

### 3.1.1 KOUNGHEUL DISTRICT

In total 918 mosquitoes were exposed on mud walls and 584 mosquitoes on cement walls. Three months after treatment, mortality was 100% for both mud and cement walls. Pirimiphos-methyl mortality was >80% until five months after spraying for both types of substrate (Table 4).

### 3.1.2 KOUMPENTOUM DISTRICT

A total of 1391 mosquitoes were exposed. The treated walls remained effective five months after spraying with greater than 80% mortality produced in every room (Table 4).

### 3.1.3 MALEM HODAR DISTRICT

A total of 682 mosquitoes were exposed on mud walls and 849 on cement walls. Pirimiphos-methyl remained effective for five months with 96% mortality on cement walls and 73.7% on mud (Table 4).

### 3.1.4 NIORO DISTRICT

For pirimiphos-methyl (Actellic CS 300), 942 mosquitoes were exposed on the walls (648 on mud and 294 on cement). The product remained effective until two months after spraying with 100% mortality in the first two months followed by a sharp decrease in efficacy (Table 4). Bendiocarb (Ficam WG 10%) was tested for three months after spraying with 216 mosquitoes tested on mud and 177 on cement. In the second month bendiocarb was no longer effective with an average of 31% mortality (Table 4). It is important to investigate the reasons for the short residual duration in this area. Spray operators require more training to ensure homogenous spray coverage and entomologists may need a refresher course on cone bioassay standard operating procedures.

In all treated districts, there was no significant variation in the effectiveness of the insecticide according to the substrate type (mud or cement) (Tables 5-9).

**TABLE 5: EFFECTIVENESS OF PIRIMIPHOS-METHYL (ACTELLIC CS 300) AGAINST A SUSCEPTIBLE INSECTARY STRAIN OF *AN. GAMBIAE* S.S. ACCORDING TO SUBSTRATE TYPE IN THE DISTRICT OF KOUNGHEUL**

| Months after IRS | | Mud (months after spraying) | | | | | Cement (months after spraying) | | | | | Total (months after spraying) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 2 | 3 | 4 | 5 | 6 | 2 | 3 | 4 | 5 | 6 |
| Exposed | Test | 188 | 180 | 210 | 171 | 169 | 165 | 120 | 90 | 122 | 87 | 353 | 300 | 300 | 293 | 256 |
| | Control | 82 | 40 | 40 | 30 | 41 | 41 | 40 | 40 | 41 | 39 | 123 | 80 | 80 | 71 | 80 |
| KD 30' | Test | 176 | 97 | 109 | 74 | 9 | 154 | 92 | 44 | 24 | 0 | 330 | 189 | 153 | 98 | 9 |
| | Control | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mort 24 h | Test | 188 | 180 | 208 | 161 | 93 | 165 | 120 | 85 | 101 | 40 | 353 | 300 | 293 | 262 | 133 |
| | Control | 2 | 0 | 0 | 1 | 0 | 1 | 2 | 1 | 0 | 0 | 3 | 2 | 1 | 1 | 0 |
| Mortality 24 h (%) | Test | 100 | 100 | 99 | 94.2 | 55 | 100 | 100* | 94.4 | 82.8 | 46 | 100 | 100 | 97.7 | 89.4 | 52 |
| | Control | 2.4 | 0 | 0 | 3.3 | 0 | 2.4 | 5 | 2.5 | 0 | 0 | 2.4 | 2.5 | 1.25 | 1.44 | 0 |

* = corrected mortality

2nd month = July ; 3rd month = August ; 4th month = September ; 5th month = October ; 6th month = November

**TABLE 6: EFFECTIVENESS OF PIRIMIPHOS-METHYL (ACTELLIC CS 300) AGAINST A SUSCEPTIBLE INSECTARY STRAIN OF *AN. GAMBIAE* S.S. ACCORDING TO SUBSTRATE TYPE IN THE DISTRICT OF KOUMPENTOUM**

| Months after IRS | | Mud (months after spraying) | | | | | Cement (months after spraying) | | | | | Total (months after spraying) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 2 | 3 | 4 | 5 | 6 | 2 | 3 | 4 | 5 | 6 |
| Exposed | Test | 222 | 180 | 161 | 150 | 169 | 62 | 120 | 121 | 85 | 121 | 284 | 300 | 282 | 235 | 290 |
| | Control | 106 | 80 | 83 | 84 | 81 | - | - | - | - | - | 106 | 80 | 83 | 84 | 81 |
| KD 30' | Test | 169 | 92 | 18 | 30 | 12 | 51 | 70 | 51 | 19 | 12 | 220 | 162 | 69 | 49 | 24 |
| | Control | 0 | 0 | 0 | 2 | 0 | - | - | - | - | - | 0 | 0 | 0 | 2 | 0 |
| Mort 24 h | Test | 22 | 175 | 141 | 125 | 121 | 62 | 116 | 105 | 79 | 74 | 284 | 291 | 246 | 204 | 195 |
| | Control | 2 | 5 | 1 | 10 | 2 | - | - | - | - | - | 2 | 5 | 1 | 10 | 2 |
| Mortality 24 h (%) | Test | 100 | 97* | 87.6 | 81.1* | 71.6 | 100 | 96.4* | 86.8 | 92* | 61.2 | 100 | 96.8* | 87.2 | 85* | 67.2 |
| | Control | 1.9 | 6.25 | 1.2 | 11.9 | 2.5 | 1.9 | 6.25 | 1.2 | 11.9 | 2.5 | 1.9 | 6.25 | 1.2 | 11.9 | 2.5 |

* = corrected mortality

2nd month = July ; 3rd month = August ; 4th month = September ; 5th month = October ; 6th month = November

**TABLE 7: EFFECTIVENESS OF PIRIMIPHOS-METHYL (ACTELLIC CS 300) AGAINST A SUSCEPTIBLE INSECTARY STRAIN OF *AN. GAMBIAE* S.S. ACCORDING TO SUBSTRATE TYPE IN THE DISTRICT OF MALEM HODAR**

| Months after IRS | | Mud (months after spraying) | | | | | Cement (months after spraying) | | | | | Total (months after spraying) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 2 | 3 | 4 | 5 | 6 | 2 | 3 | 4 | 5 | 6 |
| Exposed | Test | 226 | 124 | 122 | 90 | 120 | 240 | 193 | 174 | 60 | 182 | 466 | 317 | 296 | 150 | 302 |
| | Control | 45 | 41 | 43 | - | 41 | 90 | 40 | 43 | 40 | 40 | 135 | 81 | 83 | 40 | 81 |
| KD 30' | Test | 102 | 80 | 1 | - | 1 | 173 | 169 | 0 | - | 0 | 275 | 249 | 1 | - | 1 |
| | Control | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| Mort 24 h | Test | 207 | 121 | 30 | 70 | 14 | 238 | 193 | 40 | 59 | 40 | 445 | 314 | 70 | 129 | 54 |
| | Control | 3 | 0 | 3 | - | 1 | 6 | 0 | 3 | 4 | 0 | 9 | 0 | 6 | 4 | 1 |
| Mortality (%) | Test | 91* | 97.6 | 19* | 73.7* | 11.7 | 99.1* | 100 | 16.7 | 96* | 22 | 95.2* | 99 | 17.7* | 82.6* | 17.9 |
| | Control | 6.7 | 0 | 6.9 | - | 2.4 | 6.7 | 0 | 7.5 | 10 | 0 | 6.7 | 0 | 7.2 | 10 | 1.2 |

* = corrected mortality

2nd month = July ; 3rd month = August ; 4th month = September ; 5th month = October ; 6th month = November

**TABLE 8: EFFECTIVENESS OF PIRIMIPHOS-METHYL (ACTELLIC CS 300) AGAINST A SUSCEPTIBLE OF *AN. GAMBIAE* S.S. ACCORDING TO SUBSTRATE TYPE IN THE DISTRICT OF NIORO**

| Months after IRS | | Mud (months after spraying) | | | | | Cement (months after spraying) | | | | | Total (months after spraying) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 2 | 3 | 4 | 5 | 6 | 2 | 3 | 4 | 5 | 6 |
| Exposed | Test | 150 | 117 | 191 | 129 | 61 | 150 | 31 | 55 | 28 | 30 | 300 | 148 | 246 | 157 | 91 |
| | Control | - | - | - | - | - | 80 | 45 | 72 | 40 | 30 | 80 | 45 | 72 | 40 | 30 |
| KD 30' | Test | 121 | 4 | 69 | 3 | 0 | 115 | 0 | 26 | 1 | 0 | 236 | 4 | 95 | 4 | 0 |
| | Control | - | - | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mort 24 h | Test | 150 | 50 | 143 | 65 | 21 | 150 | 13 | 38 | 19 | 8 | 300 | 63 | 181 | 84 | 29 |
| | Control | - | - | - | - | - | 0 | 1 | 4 | 1 | 1 | 0 | 1 | 4 | 1 | 1 |
| Mortality 24 h (%) | Test | 100 | 42.7 | 73* | 50.4 | 34.4 | 100 | 41.9 | 69* | 67.8 | 26.7 | 100 | 42.6 | 72* | 53.5 | 31.9 |
| | Control | 0 | 2.2 | 5.5 | 2.5 | 3.3 | 0 | 2.2 | 5.5 | 2.5 | 3.3 | 0 | 2.2 | 5.5 | 2.5 | 3.3 |

* = corrected mortality

2nd month = July ; 3rd month = August ; 4th month = September ; 5th month = October ; 6th month = November

**TABLE 9: EFFECTIVENESS OF BENDIOCARB (FICAM WG 10%) AGAINST A SUSCEPTIBLE INSECTARY STRAIN OF *AN. GAMBIAE* S.S. ACCORDING TO SUBSTRATE TYPE IN THE DISTRICT OF NIORO**

| Months after IRS | | Mud (months after spraying) | | | Cement (months after spraying) | | | Total (months after spraying) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | <1 | 2 | 3 | <1 | 2 | 3 | <1 | 2 | 3 |
| Exposed | Test | 90 | 96 | 30 | 57 | 60 | 60 | 147 | 156 | 90 |
| | Control | 43 | 41 | 32 | - | - | - | 43 | 41 | 32 |
| KD 30' | Test | 85 | 37 | 0 | 51 | 11 | 0 | 136 | 48 | 0 |
| | Control | 0 | 0 | 0 | - | - | - | 0 | 0 | 0 |
| Mort 24 h | Test | 86 | 30 | 7 | 54 | 19 | 6 | 140 | 49 | 13 |
| | Control | 1 | 1 | 0 | - | - | - | 1 | 1 | 0 |
| Mortality 24 h (%) | Test | 95.5 | 31.2 | 23.3 | 94.7 | 31.7 | 10 | 95.2 | 31.4 | 14.4 |
| | Control | 2.3 | 2.4 | 0 | 2.3 | 2.4 | 0 | 2.3 | 2.4 | 0 |

* = corrected mortality

2nd month = July; 3rd month = August ; 4th month = September ; 5th month = October ; 6th month = November

## 3.2 VECTOR POPULATION DYNAMICS IN IRS DISTRICTS

### 3.2.1 KOUNGHEUL DISTRICT

*Anopheles gambiae* s.l. was the main species group caught in resting collections and human landing catches inside habitations of Koungheul District (Table 10). Vector populations increased during the rainy season. The minimum and maximum human biting rates were recorded in August and October, respectively. The greatest density caught resting indoors through PSC was in November.

TABLE 10: SPECIES COMPOSITION ACCORDING TO THE SAMPLING METHOD DURING THE RAINY SEASON **(KOUNGHEUL)**

| Month | Species | HLC | | | PSC | Total |
|---|---|---|---|---|---|---|
| | | Indoors | Outdoors | Total | | |
| August | ***An. gambiae* s.l.** | **17** | **10** | **27** | **70** | **97** |
| | *An. funestus* s.l. | 0 | 0 | 0 | 0 | 0 |
| | *An. pharoensis* | 0 | 2 | 2 | 0 | 2 |
| | *An. nili* | 0 | 0 | 0 | 0 | 0 |
| | Other *Anopheles* | 0 | 0 | 0 | 0 | 0 |
| September | ***An. gambiae* s.l.** | **15** | **21** | **36** | **39** | **75** |
| | *An. funestus* s.l. | 0 | 0 | 0 | 1 | 1 |
| | *An. pharoensis* | 0 | 1 | 1 | 0 | 1 |
| | *An. nili* | 0 | 0 | 0 | 0 | 0 |
| | Other *Anopheles* | 0 | 0 | 0 | 0 | 0 |
| October | ***An. gambiae* s.l.** | **15** | **26** | **41** | **36** | **77** |
| | *An. funestus* s.l. | 0 | 0 | 0 | 0 | 0 |
| | *An. pharoensis* | 1 | 0 | 1 | 0 | 1 |
| | *An. nili* | 0 | 0 | 0 | 0 | 0 |
| | *An. rufipes* | 0 | 0 | 0 | 2 | 2 |
| November | ***An. gambiae* s.l.** | **20** | **12** | **32** | **151** | **183** |
| | *An. funestus* s.l. | 0 | 0 | 0 | 1 | 1 |
| | *An. pharoensis* | 0 | 0 | 0 | 0 | 0 |
| | *An. nili* | 0 | 0 | 0 | 0 | 0 |
| | *An. rufipes* | 0 | 0 | 0 | 5 | 5 |
| Total | ***An. gambiae* s.l.** | **67** | **69** | **136** | **296** | **432** |
| | *An. funestus* s.l. | 0 | 0 | 0 | **2** | **2** |
| | *An. pharoensis* | 1 | 3 | 4 | 0 | 4 |
| | *An. nili* | 0 | 0 | 0 | 0 | 0 |
| | *An. rufipes* | 0 | 0 | 0 | 7 | 7 |

**TABLE 11 A:** HUMAN BITING RATE AND INDOOR RESTING DENSITY OF *ANOPHELES GAMBIAE* S.L. FEMALES IN **KOUNGHEUL DISTRICT** (COMBINED RESULTS FOR SPRAYED AND UNSPRAYED VILLAGES)

| | **Human biting rate** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Indoors | | | | | Outdoors | | | | | Total | | | | |
| | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total |
| Man nights | 18 | 18 | 18 | 18 | 72 | 18 | 18 | 18 | 18 | 72 | 36 | 36 | 36 | 36 | 144 |
| Total *An. gambiae* s.l. | 17 | 15 | 15 | 20 | 67 | 10 | 21 | 26 | 12 | 69 | 27 | 36 | 41 | 32 | 136 |
| Bites /man/ night | **0.9** | **0.8** | **0.8** | **1.1** | **0.9** | **0.5** | **1.2** | **1.4** | **0.7** | **1.0** | **0.75** | **1** | **1.1** | **0.9** | **0.9** |

| | **PSC** | | | | |
|---|---|---|---|---|---|
| | Aug | Sept | Oct | Nov | Total |
| Number of rooms | 30 | 30 | 30 | 30 | 120 |
| Total *An. gambiae* s.l. | 70 | 39 | 36 | 151 | 296 |
| Indoor Resting Density (females/room) | 2.3 | 1.3 | 1.2 | 5 | 2.5 |

**TABLE 11B:** HUMAN BITING RATE (HBR) FOR *ANOPHELES GAMBIAE* S.L. IN SPRAYED AND UNSPRAYED VILLAGES **(KOUNGHEUL)**

| | **Sprayed villages** | | | | | **Internal control** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Aug** | **Sept** | **Oct** | **Nov** | **Total** | **Aug** | **Sept** | **Oct** | **Nov** | **Total** |
| Man/night | 24 | 24 | 24 | 24 | 96 | 12 | 12 | 12 | 12 | 48 |
| Total *An. gambiae* s.l. | 24 | 29 | 24 | 22 | 99 | 3 | 7 | 17 | 10 | 37 |
| **Human biting rate (bites/man/night)** | **1** | **1.2** | **1** | **0.9** | **1** | **0.25** | **0.6** | **1.4** | **0.8** | **0.8** |

**TABLE 11C:** INDOOR RESTING DENSITY FOR *ANOPHELES GAMBIAE* S.L. FEMALES IN SPRAYED AND UNSPRAYED VILLAGES **(KONGHEUL)**

| | **Sprayed villages** | | | | | **Internal control** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Aug** | **Sept** | **Oct** | **Nov** | **Total** | **Aug** | **Sept** | **Oct** | **Nov** | **Total** |
| **Number of Rooms** | 20 | 20 | 20 | 20 | 80 | 10 | 10 | 10 | 10 | 40 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Total *An. gambiae* s.l.** | 17 | 7 | 12 | 67 | 103 | 53 | 32 | 24 | 84 | 193 |
| **Density (females/room)** | **0.85** | **0.35** | **0.6** | **3.35** | **1.3** | **5.3** | **3.2** | **2.4** | **8.4** | **4.8** |

### Population density

The analysis was made only for *Anopheles gambiae* s.l. Biting rates were very low with an average of 1 bite per man per night inside and outside houses (Table 11a) in treated villages as in the control village (table 11b). The indoor resting density ranged from 1.3 females/room (September) to 5 females/room (November). In the internal control village the average was 4.8 compared to 1.3 females per room in the sprayed villages respectively (table 11c). These results indicate that vectors were largely endophilic in the internal control during the monitoring period but less in the sprayed villages from August to October.

### Parity rate

The parity rate was determined for females captured during HLC. In total between August and November the mean parity rate was 63.3% in treated villages and 66.6% in the internal control village (Table 12), indicating no difference in age structure.

**TABLE 12:** PARITY RATE OF *ANOPHELES GAMBIAE* S.L. IN SPRAYED AND UNSPRAYED VILLAGES IN **KOUNGHEUL DISTRICT**

| Monitoring month | Sprayed villages | | | Internal control | | |
|---|---|---|---|---|---|---|
| | Total caught | Dissected | Parity rate | Total caught | Dissected | Parity rate |
| August | 24 | 19 | 52.6% (10/19) | 3 | 2 | 50% (1/2) |
| September | 29 | 21 | 66.7% (14/21) | 7 | 4 | 25% (1/4) |
| October | 24 | 12 | 50% (6/6) | 17 | 10 | 70% (7/10) |
| November | 22 | 8 | 100% (8/8) | 10 | 5 | 100% (5/5) |
| **Total** | **99** | **60** | **63.3% (38/60)** | **37** | **21** | **66.6% (14/21)** |

## 3.2.2 KOUMPENTOUM DISTRICT

### Species Composition

*Anopheles gambiae* s.l. was the main species caught in human landing catches and indoor resting collections in the district of Koumpentoum (Table 13). The density of *An. gambiae* s.l. increased during the rainy season and reached the peak in September before declining. Average resting density across months was 2.4 in the sprayed villages and 3.3 in the unsprayed village.

### Population density

The biting rate of *An. gambiae* s.l. in the district of Koumpentoum was highest in September and lowest in November both inside and outside houses, averaging 2.3 and 0.2, respectively, per human night (Table 14a). The mean biting rate recorded in treated villages was low (1.2 bites per human/night) but this was about two times higher than the unsprayed control villages (both internal and external) that had 0.6 bites per human/night (Table 14a). Similarly, *An. gambiae* s.l. resting densities were generally low, but the highest densities were in September with an average of 4 females per room/night (Table 14c). There was a trend of greater indoor densities in the internal control village (an average of 3.3 females per room) with a peak in August of 5.5 females per room compared to treated villages. In the external control village densities were lower, with 1 female captured per room (Table 14c).

**TABLE 13:** SPECIES COMPOSITION ACCORDING TO THE SAMPLING METHOD DURING THE RAINY SEASON IN **KOUMPENTOUM DISTRICT**

| Month | Species | HLC | | | PSC | Total |
|---|---|---|---|---|---|---|
| | | Indoor | Outdoor | Total | | |
| August | *An. gambiae* s.l. | 18 | 12 | 30 | 110 | 140 |
| | *An. funestus* s.l. | 0 | 0 | 0 | 1 | 1 |
| | Other *Anopheles* | 0 | 0 | 0 | 0 | 0 |
| September | *An. gambiae* s.l. | 37 | 46 | 83 | 118 | 201 |
| | *An. funestus* s.l. | 0 | 0 | 0 | 0 | 0 |
| | Other *Anopheles* | 0 | 0 | 0 | 0 | 0 |
| October | *An. gambiae* s.l. | 21 | 6 | 27 | 58 | 85 |
| | *An. funestus* s.l. | 0 | 0 | 0 | 0 | 0 |
| | *An. rufipes* | 0 | 0 | 0 | 1 | 1 |
| November | *An. gambiae* s.l. | 3 | 3 | 6 | 37 | 43 |
| | *An. funestus* s.l. | 0 | 0 | 0 | 0 | 0 |
| | *An. rufipes* | 0 | 0 | 0 | 1 | 1 |
| Total | *An. gambiae* s.l. | 79 | 67 | 146 | 323 | 469 |
| | *An. funestus* s.l. | 0 | 0 | 0 | 1 | 1 |
| | *An. rufipes* | 0 | 0 | 0 | 2 | 2 |

**TABLE 14A**: HUMAN BITING RATE AND INDOOR RESTING DENSITY OF *ANOPHELES GAMBIAE* S.L. FEMALES DURING THE RAINY SEASON IN KOUMPENTOUM DISTRICT **(COMBINED FOR SPRAYED AND UNSPRAYED VILLAGES)**

| | Human biting rate | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Indoors | | | | | Outdoors | | | | | Total | | | | |
| | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total |
| Man nights | 18 | 18 | 18 | 18 | 72 | 18 | 18 | 18 | 18 | 72 | 36 | 36 | 36 | 36 | 144 |
| Total *An. gambiae* s.l. | 18 | 37 | 21 | 3 | 79 | 12 | 46 | 6 | 3 | 67 | 30 | 83 | 27 | 6 | 146 |
| **Bites / man / night** | **1** | **2** | **1.17** | **0.2** | **1.1** | **0.7** | **2.6** | **0.33** | **0.2** | **0.9** | **0.8** | **2.3** | **0.75** | **0.2** | **1** |

| | PSC | | | | |
|---|---|---|---|---|---|
| | Aug | Sept | Oct | Nov | Total |
| Number of rooms | 30 | 30 | 30 | 30 | 120 |
| Total *An. gambiae* s.l. | 110 | 118 | 58 | 37 | 323 |
| **Density per room** | **3.7** | **3.9** | **1.9** | **1.2** | **2.7** |

**TABLE 14B:** HUMAN BITING RATE (HBR) FOR *ANOPHELES GAMBIA*E S.L. IN SPRAYED AND UNSPRAYED VILLAGES IN **KOUMPENTOUM**

| | Sprayed villages | | | | | Internal control | | | | | External control | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total |
| Man - night | 24 | 24 | 24 | 24 | 96 | 12 | 12 | 12 | 12 | 48 | 12 | - | 12 | - | 24 |
| Total *An. gambiae* s.l. | 27 | 60 | 25 | 3 | 115 | 3 | 23 | 2 | 3 | 31 | 9 | - | 6 | - | 15 |
| **Biting rate (b/m/n)** | **1.1** | **2.5** | **1** | **0.1** | **1.2** | **0.3** | **1.9** | **0.2** | **0.3** | **0.6** | **0.8** | **-** | **0.5** | **-** | **0.6** |

**TABLE 14C:** INDOOR RESTING DENSITY FOR *ANOPHELES GAMBIAE* FEMALES IN SPRAYED AND UNSPRAYED VILLAGES IN **KOUMPENTOUM**

| | Sprayed villages | | | | | Internal control | | | | | External control | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total |
| Number of rooms | 20 | 20 | 20 | 20 | 80 | 10 | 10 | 10 | 10 | 40 | 10 | - | 10 | - | 20 |
| Total *An. gambiae* s.l. | 55 | 77 | 42 | 18 | 192 | 55 | 41 | 16 | 19 | 131 | 12 | - | 6 | - | 18 |
| Density (females/room) | **2.8** | **3.9** | **2.1** | **0.9** | **2.4** | **5.5** | **4.1** | **1.6** | **1.9** | **3.3** | **1.2** | **-** | **0.6** | **-** | **0.9** |

### Parity rate

The number of dissected biting females was very low in the control villages. The overall number dissected was too few for accurate comparison of the parity rate for *An. gambiae* s.l. (Table 15).

**TABLE 15**: PARITY RATE OF HUMAN BITING FEMALE *ANOPHELES GAMBIAE* S.L. COLLECTED BY HLC IN TREATED AND CONTROL VILLAGES IN THE DISTRICT OF **KOUMPENTOUM**

| Months of surveillance | Sprayed villages | | | Internal control | | | External control | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | Dissected | Parity | Total | Dissected | Parity | Total | Dissected | Parity |
| August | 27 | 21 | 42.8% (9/21) | 3 | 3 | 33,3% (1/3) | 9 | 6 | 66.7% (4/9) |
| September | 60 | 30 | 36.7% (11/30) | 23 | 5 | 60% (3/5) | - | - | - |
| October | 25 | 8 | 62.5% (5/8) | 2 | 1 | 0% | 6 | 3 | 66.7 (2/3) |
| November | 3 | 0 | 0% | 3 | 2 | 100% (2/2) | - | - | - |
| **Total** | **115** | **59** | **42% (25/59)** | **31** | **11** | **55% (6/11)** | **15** | **9** | **67% (6/9)** |

## 3.2.3 MALEM HODAR DISTRICT

### Species composition

*Anopheles gambiae* s.l. was the main species caught in human landing catches and indoor resting catches in Hodar Malem District (Table 16).

### Population density

The population density of host-seeking *An. gambiae* s.l. was relatively low in the district of Malem Hodar with an average biting rate of less than one mosquito per person/night both inside and outside houses as measured by HLC (Table 16a). The mean biting rate was very low in treated villages (0.5 bites per human/night), but was double (1.3 bites per human/night) in the control villages (Table 16b). The mosquito density was also lower in treated villages and relatively higher in the control villages. A clear trend of increased densities indoors was observed towards the end of the rainy season in the sprayed villages. The indoor resting densities were greatest in the external control villages (8 females/room/night) and internal controls (4.7 females/room/night) compared with treated villages (2.2 females/room/night) (Table 16c).

### Parity rate

The results showed that parity rates were higher in control districts compared to the treated villages with a mean parity rate of 63% in the external control and 60% in the internal control versus 43% in sprayed villages (Table 17).

**TABLE 16:** SPECIES COMPOSITION OF THE MOSQUITO ACCORDING TO THE SAMPLING METHOD IN THE DISTRICT OF **MALEM HODAR**

| Month | Species | HLC | | | PSC | Total |
|---|---|---|---|---|---|---|
| | | Indoors | Outdoors | Total | | |
| August | *An. gambiae* s.l. | 11 | 8 | 19 | 87 | 106 |
| | *An. funestus* s.l. | 0 | 0 | 0 | 0 | 0 |
| | *An. pharoensis* | 1 | 0 | 1 | 0 | 1 |
| September | *An. gambiae* s.l. | 19 | 13 | 32 | 50 | 82 |
| | *An. funestus* s.l. | 0 | 0 | 0 | 0 | 0 |
| | *An. pharoensis* | 1 | 0 | 1 | 0 | 1 |
| October | *An. gambiae* s.l. | 12 | 15 | 27 | 123 | 150 |
| | *An. funestus* s.l. | 0 | 0 | 0 | 0 | 0 |
| | *An. pharoensis* | 0 | 0 | 0 | 0 | 0 |
| November | *An. gambiae* s.l. | 20 | 9 | 29 | 103 | 132 |
| | *An. funestus* s.l. | 0 | 0 | 0 | 1 | 1 |
| | *An. pharoensis* | 0 | 0 | 0 | 0 | 0 |
| Total | *An. gambiae* s.l. | 62 | 45 | 107 | 363 | 470 |
| | *An. funestus* s.l. | 0 | 0 | 0 | 1 | 1 |
| | *An. pharoensis* | 2 | 0 | 2 | 0 | 2 |
| | | | | | | |

**TABLE 16 A: HUMAN BITING RATE AND INDOOR RESTING DENSITITIES FOR *ANOPHELES GAMBIAE* S.L. IN MALEM HODAR DISTRICT (COMBINED FOR SPRAYED AND UNSPRAYED VILLAGES)**

| | **Human biting rates** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Indoors | | | | | Outdoors | | | | | Total | | | | |
| | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total |
| Man nights | 18 | 18 | 18 | 18 | 72 | 18 | 18 | 18 | 18 | 72 | 36 | 36 | 36 | 36 | 144 |
| Total *An. gambiae* s.l. | 11 | 19 | 12 | 20 | 62 | 8 | 13 | 15 | 9 | 45 | 19 | 32 | 27 | 29 | 107 |
| Biting rate (b/m/n) | 0.6 | 1.1 | 0.7 | 1.1 | 0.9 | 0.4 | 0.7 | 0.8 | 0.5 | 0.6 | 0.5 | 0.9 | 0.8 | 0.8 | 0.7 |

| | **PSC** | | | | |
|---|---|---|---|---|---|
| | Aug | Sept | Oct | Nov | Total |
| Total rooms | 30 | 30 | 30 | 30 | 120 |
| Total *An. gambiae* s.l. | 87 | 50 | 123 | 103 | 363 |
| **Density per room** | **2.9** | **1.7** | **4.1** | **3.4** | **3.0** |

**TABLE 16 B:** HUMAN BITING RATE OF *ANOPHELES GAMBIAE* S.L. IN TREATED AND CONTROL VILLAGES IN **MALEM HODAR DISTRICT**

| | **Sprayed villages** | | | | | **Internal control** | | | | | **External control** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total |
| Man nights | 24 | 24 | 24 | 24 | 96 | 12 | 12 | 12 | 12 | 48 | 12 | - | 12 | - | 24 |
| Total *An. gambiae* s.l. | 8 | 13 | 11 | 13 | 45 | 11 | 19 | 16 | 16 | 62 | 18 | - | 13 | - | 31 |
| **Biting rate (b/m/n)** | **0.3** | **0.5** | **0.5** | **0.5** | **0.5** | **0.9** | **1.6** | **1.3** | **1.3** | **1.3** | **1.5** | **-** | **1** | **-** | **1.3** |

**TABLE 16 C:** INDOOR RESTING DENSITY FOR *ANOPHELES GAMBIAE* FEMALES IN SPRAYED AND UNSPRAYED VILLAGES IN **MALEM HODAR**

| | **Sprayed villages** | | | | | **Internal control** | | | | | **External control** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total |
| Number of rooms | 20 | 20 | 20 | 20 | 80 | 10 | 10 | 10 | 10 | 40 | 10 | - | 10 | - | 20 |
| Total *An. gambiae* s.l. | 27 | 32 | 69 | 48 | 176 | 60 | 18 | 54 | 55 | 187 | 76 | - | 84 | - | 160 |
| Indoor Resting rate (number of females/room) | **1.4** | **1.6** | **3.5** | **2.4** | **2.2** | **6** | **1.8** | **5.4** | **5.5** | **4.7** | **7.6** | **-** | **8.4** | **-** | **8** |

**TABLE 17:** PARITY RATE OF FEMALE *ANOPHELES GAMBIAE* S.L. COLLECTED BY HLC IN TREATED AND CONTROL VILLAGES IN THE DISTRICT OF **MALEM HODAR**

| Month | Sprayed village | | | Internal control | | | External control | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | Dissected | Parity | Total | Dissected | Parity | Total | Dissected | Parity |
| August | 8 | 2 | 0% | 11 | 4 | 50% (2/4) | 18 | 9 | 55,5% (5/9) |
| September | 13 | 11 | 27% (3/11) | 19 | 16 | 75% (12/16) | - | - | - |
| October | 11 | 4 | 75% (3/4) | 16 | 9 | 55% (5/9) | 13 | 7 | 71,4% (5/7) |
| November | 13 | 11 | 54% (6/11) | 16 | 14 | 50% (7/14) | - | - | - |
| Total | 45 | 28 | 43% (12/28) | 62 | 43 | 60% (26/43) | 31 | 16 | 63% (10/16) |

## 3.2.4 NIORO DISTRICT

### Species composition

*Anopheles gambiae* s.l. and *Anopheles funestus* s.l. were the main species caught by HLC and indoor resting collections in Nioro District with respectively 728 and 342 specimens collected (Table 18). Populations of both *An. gambiae* s.l. and *An. funestus* s.l. reached peak indoor resting densities in August.

**TABLE 18:** SPECIES COMPOSITION OF THE MOSQUITO ACCORDING TO THE SAMPLING METHOD IN THE DISTRICT OF **NIORO**

| Month | Species | HLC | | | PSC | Total |
|---|---|---|---|---|---|---|
| | | Indoors | Outdoors | Total | | |
| August | *An. gambiae* s.l. | 18 | 6 | 24 | 276 | 300 |
| | *An. funestus* s.l. | 19 | 24 | 43 | 87 | 130 |
| | Other *Anopheles* | 0 | 0 | 0 | 0 | 0 |
| September | *An. gambiae* s.l. | 33 | 23 | 56 | 33 | 89 |
| | *An. funestus* s.l. | 9 | 9 | 18 | 8 | 26 |
| | *An. pharoensis* | 0 | 1 | 1 | 0 | 1 |
| | *An. squamosus* | 2 | 1 | 3 | 0 | 3 |
| October | *An. gambiae* s.l. | 24 | 17 | 41 | 112 | 153 |
| | *An. funestus* s.l. | 4 | 20 | 24 | 21 | 45 |
| | *An. pharoensis* | 0 | 0 | 0 | 0 | 0 |
| | *An rufipes* | 3 | 5 | 8 | 0 | 8 |
| November | *An. gambiae* s.l. | 26 | 24 | 50 | 136 | 186 |
| | *An. funestus* s.l. | 25 | 51 | 76 | 65 | 141 |
| | Other *Anopheles* | 0 | 0 | 0 | 0 | 0 |
| Total | ***An. gambiae* s.l.** | **101** | **70** | **171** | **557** | **728** |
| | ***An. funestus* s.l.** | **57** | **104** | **161** | **181** | **342** |
| | *An. pharoensis* | 0 | 1 | 1 | 0 | 1 |
| | Other Anopheles | 5 | 6 | 11 | 0 | 11 |

**Population densities**

The results recorded in Nioro District show that biting densities of *An. gambiae* s.l. were low inside and outside houses (Table 19a). The HBR in the internal control village (1.7 bites per human/night) was low but about two times higher than that recorded in treated villages (Table 19 b). The HBR in the external control was lowest at only 0.08 bites per human/night.

The density resting indoors was much greater in the internal control village at 8.7 females per room/night than in treated villages at 1.7 females per room per night and the external control at 0.3 females per room/night. In this district a significant population of *An. funestus* s.l. was documented in the villages of Bamba Diakhatou and Ndramé Ndimb (Table 19 d).

**TABLE 19 A: HUMAN BITING RATE AND INDOOR RESTING DENSITITIES OF *ANOPHELES GAMBIAE* S.L. IN NIORO DISTRICT (COMBINED FOR SPRAYED AND UNSPRAYED VILLAGES)**

| | Human biting rates | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Indoors | | | | | Outdoors | | | | | Total | | | | |
| | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total |
| Man nights | 18 | 18 | 18 | 18 | 72 | 18 | 18 | 18 | 18 | 72 | 36 | 36 | 36 | 36 | 144 |
| Total *An. gambiae* s.l. | 18 | 33 | 24 | 26 | 101 | 6 | 23 | 17 | 24 | 70 | 24 | 56 | 41 | 50 | 171 |
| **Biting rate (bites /person/night)** | **1** | **1.8** | **1.3** | **1.4** | **1.4** | **0.3** | **1.3** | **0.9** | **1.3** | **1** | **0.7** | **1.6** | **1.1** | **1.4** | **1.2** |

**NB: One village (Ndramé Ndimb) was sprayed with FICAM in September.**

| | PSC | | | | |
|---|---|---|---|---|---|
| | Aug | Sept | Oct | Nov | Total |
| Number of rooms | 30 | 30 | 30 | 30 | 120 |
| Total *An. gambiae* s.l. | 276 | 33 | 112 | 136 | 557 |
| Density per room | 9.2 | 1.1 | 3.7 | 4.5 | 4.6 |

**TABLE 19 B:** HUMAN BITING RATE OF *ANOPHELES GAMBIAE* S.L. IN TREATED VILLAGES AND CONTROLS IN **NIORO DISTRICT**

| | Sprayed villages | | | | | Internal control | | | | | External control | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aug | Sept. | Oct. | Nov. | Total | Aug | Sept. | Oct. | Nov. | Total | Aug | Sept. | Oct. | Nov. | Total |
| Man nights | 12 | 24 | 24 | 24 | 84 | 24 | 12 | 12 | 12 | 60 | 12 | - | 12 | - | 24 |
| Total *An. gambiae* s.l. | 1 | 37 | 10 | 23 | 71 | 23 | 19 | 31 | 27 | 100 | 2 | - | 0 | - | 2 |
| Biting rate (bites/man/night) | **0.1** | **1.5** | **0.4** | **1** | **0.8** | **1** | **1.6** | **2.6** | **2.3** | **1.7** | **0.2** | **-** | **0** | **-** | **0.08** |

**TABLE 19 C:** INDOOR RESTING DENSITY OF *ANOPHELES GAMBIAE* S.L. FEMALES IN SPRAYED AND UNSPRAYED VILLAGES IN **NIORO DISTRICT**

| | Sprayed villages | | | | | Internal control | | | | | External control | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total | Aug | Sept | Oct | Nov | Total |
| Nb. rooms | 10 | 20 | 20 | 20 | 70 | 20 | 10 | 10 | 10 | 50 | 10 | - | 10 | - | 20 |
| Total *An. gambiae* s.l. | 22 | 21 | 18 | 60 | 121 | 254 | 12 | 94 | 76 | 436 | 3 | - | 2 | - | 5 |
| Resting rate | **2.2** | **1.1** | **0.9** | **3** | **1.7** | **12.7** | **1.2** | **9.4** | **7.6** | **8.7** | **0.3** | **-** | **0.2** | **-** | **0.3** |

**TABLE 19 D:** HUMAN BITING RATE OF *ANOPHELES FUNESTUS* S.L. IN **NIORO DISTRICT**

| Month | HLC | | | PSC |
|---|---|---|---|---|
| | Indoors | Outdoors | Total | |
| August | 19 (1.05 b/m/n) | 24 1.3 b/m/n ) | 43 (1.2 b/m/n ) | 87 (2.9 f/r) |
| September | 9 (0.5 b/m/n ) | 9 (0.5 b/m/n ) | 18 (0.5 b/m/n ) | 8 (0.3 f/r) |
| October | 4 (0.2 b/m/n ) | 20 (1.1 b/m/n ) | 24 (0.6 b/m/n ) | 21 (0.7 f/r) |
| November | 25 (1.4 b/m/n ) | 51 (2.8 b/m/n ) | 76 (2 b/m/n ) | 65 (2.2 f/r) |

BMN = Bites/man/night, f/r = females per room

### Parity rate

Parity rates in Nioro District were comparable between the internal control village and sprayed villages with 52% and 50%, respectively. Only two specimens were caught in the external control village during monitoring (Table 20).

**TABLE 20**: PARITY RATE OF FEMALE *ANOPHELES GAMBIAE* S.L. BETWEEN TREATED AND CONTROL VILLAGES IN **NIORO DISTRICT**

| Month | Sprayed villages | | | Internal control | | | External control | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | Dissected | Parity | Total | Dissected | Parity | Total | Dissected | Parity |
| August | 1 | 1 | 0% | 23 | 12 | 25% (3/12) | 2 | 0 | |
| September | 37 | 18 | 56% (10/18) | 19 | 13 | 54% (7/13) | - | - | - |
| October | 10 | 4 | 25% (1/4) | 31 | 23 | 57% (13/23) | 0 | 0 | |
| November | 23 | 15 | 53% (8/15) | 27 | 15 | 67% (10/15) | - | - | - |
| Total | 71 | 38 | 50% (19/38) | 100 | 63 | 52% (33/63) | 2 | 0 | |

## 3.3 UNSPRAYED DISTRICTS

### 3.3.1 VELINGARA DISTRICT

### Species composition

*Anopheles gambiae* s.l. was the main species caught in HLC and resting collections in Velingara District (Table 21).

### Population density

The densities of human biting of *An. gambiae* s.l. were very high at the start of the rainy season, averaging 42.8 bites per human/night in August (indoors and outdoors) compared with 5.7 in October. Despite the high biting rates in August indoors and outdoors, an average of only 3 females per room were collected by PSC in August (Table 22 a).

**TABLE 21: SPECIES COMPOSITION ACCORDING TO THE SAMPLING METHOD IN THE DISTRICT OF VÉLINGARA**

| Month | Species | HLC | | | PSC | Total |
|---|---|---|---|---|---|---|
| | | Indoors | Outdoors | Total | | |
| August | *An. gambiae* s.l. | 437 | 590 | 1027 | 60 | 1 087 |
| | *An. funestus* s.l. | 0 | 0 | 0 | 0 | 0 |
| | *An. pharoensis* | 0 | 1 | 1 | 0 | 1 |
| | *An. nili* | 2 | 0 | 2 | 0 | 2 |
| | Other *Anopheles* | 0 | 0 | 0 | 0 | 0 |
| October | *An. gambiae* s.l. | 58 | 86 | 144 | 28 | 172 |
| | *An. funestus* s.l. | 0 | 1 | 1 | 8 | 9 |
| | *An. pharoensis* | 0 | 0 | 0 | 1 | 1 |
| | *An. nili* | 0 | 0 | 0 | 0 | 0 |
| | Other *Anopheles* | 0 | 0 | 0 | 0 | 0 |
| Total | *An. gambiae* s.l. | **495** | **676** | **1171** | **88** | **1 259** |
| | *An. funestus* s.l. | 0 | 1 | 1 | 8 | 9 |
| | *An. pharoensis* | 0 | 1 | 1 | 1 | 2 |
| | *An. nili* | 2 | 0 | 2 | 0 | 2 |
| | Other *Anopheles* | 0 | 0 | 0 | 0 | 0 |

**TABLE 22 A**: HUMAN BITING RATE AND INDOOR RESTING DENSITITIES FOR *ANOPHELES GAMBIAE* S.L. IN **VÉLINGARA DISTRICT** (AUG-OCTOBER 2015)

| | HLC | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Indoors | | | Outdoors | | | Total | | |
| | Aug | Oct | Total | Aug | Oct | Total | Aug | Oct | Total |
| Nemataba | 163 | 27 | 190 | 240 | 60 | 300 | 403 | 87 | 490 |
| Madina Dianguet | 274 | 28 | 302 | 350 | 23 | 373 | 624 | 51 | 675 |
| Total *An. gambiae* s.l. | 437 | 55 | 492 | 590 | 83 | 673 | 1027 | 138 | 1165 |
| Human biting rate bites/man/night | **36.4** | **4.6** | **20.5** | **49.2** | **6.9** | **28.0** | **42.8** | **5.7** | **24.3** |

| | PSC | | |
|---|---|---|---|
| | Aug | Oct | Total |
| Nemataba | 21 | 7 | 28 |
| Madina Dianguet | 39 | 21 | 60 |
| Total *An. gambiae* s.l. | 60 | 28 | 88 |
| Density per room | 3 | 1.4 | 2.2 |

**Parity rate**

Parity rates were relatively higher at the end of the rainy season (October) in Madina Dianguet and comparable between endophagic females and exophagic females in Nemataba. Changes in parity rate between August and October in Nemataba were minimal. (Table 22 B).

**TABLE 22 B: PARITY RATE FOR *ANOPHELES GAMBIAE* S.L. IN VÉLINGARA DISTRICT (AUG-OCTOBER 2015)**

| Month | Indoor | | | | | | Outdoor | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | August | | | October | | | August | | | October | | |
| Villages | D | P | PR% | D | P | PR% | D | P | PR% | D | P | PR% |
| Nemataba | 140 | 107 | 76.4 | 26 | 20 | 76.9 | 150 | 92 | 61.3 | 50 | 35 | 70 |
| Madina Dianguet | 153 | 67 | 43.8 | 28 | 28 | 100 | 145 | 68 | 46.9 | 19 | 18 | 94.7 |
| Total | **293** | **174** | **59.4** | **54** | **48** | **88.9** | **295** | **160** | **54.2** | **69** | **53** | **76.8** |

D = number dissected, P = parous, PR = %parity rate

## 3.3.2 KEDOUGOU DISTRICT

### Species composition

*An. gambiae* s.l. was the main human biting species present (Table 23). Other species of *Anopheles* such as *An. nili, An. ziemanni*, and *An. pharoensis* were collected in very small numbers. Of 151 *An. gambiae* s.l. identified by PCR to species 6% were *An. coluzzii*, 13% *An. arabiensis*, and 81% *An. gambiae* s.s.

**TABLE 23:** SPECIES COMPOSITION OF THE MOSQUITO ACCORDING TO THE SAMPLING METHOD IN THE DISTRICT OF **KÉDOUGOU**

| Month | Species | HLC | | | PSC | Total |
|---|---|---|---|---|---|---|
| | | Indoors | Outdoors | Total | | |
| July | *An. gambiae* s.l. | 785 | 773 | 1558 | 45 | 1603 |
| | *An. rufipes* | 0 | 0 | 0 | 1 | 1 |
| October | *An. gambiae* s.l. | 325 | 303 | 628 | 35 | 663 |
| | *An. pharoensis* | 2 | 1 | 3 | 0 | 3 |
| | *An. nili* | 3 | 1 | 4 | 0 | 4 |
| | *An. ziemanni* | 0 | 3 | 3 | 0 | 3 |
| | *An. rufipes* | 0 | 0 | 0 | 1 | 1 |
| Total | *An. gambiae* s.l. | 1,110 | 1,076 | 2,186 | 80 | 2,266 |
| | *An. pharoensis* | 2 | 1 | 3 | 0 | 3 |
| | *An. nili* | 3 | 1 | 4 | 0 | 4 |
| | *An. rufipes* | 0 | 0 | 0 | 2 | 2 |

### Population densities

In Kedougou District human biting rates were very high in July at 64.9 bites per human/night (mean indoors and outdoors). In October the biting rate was still high at 26.2 bites per human/night (Table 24a). The mean human biting rate was at least twice as large in Tomboronkoto as in Bandafassi Village. The low indoor resting density of just 2 females per room/night compared to the high indoor biting rates may indicate a trend of exophily (Table 24a).

**TABLE 24 A: HUMAN BITING RATE AND INDOOR RESTING DENSITITIES FOR *ANOPHELES GAMBIAE* S.L. IN KEDOUGOU DISTRICT**

| | HLC | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Indoors | | | Outdoors | | | Total | | |
| | July | Oct. | Total | July | Oct. | Total | July | Oct. | Total |
| Tomboronkoto | 532 | 234 | 766 | 457 | 263 | 720 | 989 | 497 | 1486 |
| Bandafassi | 253 | 91 | 344 | 316 | 40 | 356 | 569 | 131 | 700 |
| Man nights | 12 | 12 | 24 | 12 | 12 | 24 | 24 | 24 | 48 |
| Total *An. gambiae* s.l. | 785 | 325 | 1110 | 773 | 303 | 1076 | 1558 | 628 | 2 186 |
| Human biting rate (b/m/n) | **65.4** | **27.1** | **46.2** | **64.4** | **25.2** | **44.8** | **64.9** | **26.2** | **45.5** |

| | PSC | | |
|---|---|---|---|
| | July | Oct. | Total |
| Tomboronkoto | 20 | 22 | 42 |
| Bandafassi | 25 | 13 | 38 |
| Number of rooms | 20 | 20 | 40 |
| Total *An. gambiae* s.l. | 45 | 35 | 80 |
| **Density per room** | **2.3** | **1.7** | **2** |

### Parity rate

The parity rate of *An. gambiae* s.l. was much higher in October than in July in both villages and for indoor and outdoor collections (Table 24b).

**TABLE 24 B:** PARITY RATE OF FEMALE *ANOPHELES GAMBIAE* S.L. IN UNSPRAYED VILLAGES IN THE DISTRICT OF **KÉDOUGOU**

| | Indoors | | | | Outdoors | | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | July | | October | | July | | October | | July | | October | |
| | D | P(PR) | D | P(PR) | D | P(PR) | D | P(PR) | D | P(PR) | D | P(PR) |
| Tomboronkoto | 203 | 89 (43.8) | 154 | 107 (69.5) | 132 | 48 (36.4) | 114 | 86 (75.4) | 335 | 137 (40.9) | 268 | 193 (72) |
| Bandafassi | 72 | 39 (54.2) | 89 | 74 (83.1) | 173 | 76 (43.9) | 28 | 21 (75) | 245 | 115 (46.9) | 117 | 95 (81.2) |
| Total | 275 | 128 (46.5) | 243 | 181 (74.5) | 305 | 124 (40.6) | 142 | 107 (75.3) | 580 | 252 (43.4) | 385 | 288 (74.8) |

D = number dissected, P = parous, PR = %parity rate

## 3.3.3 TAMBACOUNDA DISTRICT

**VECTOR SURVEILLANCE WAS CARRIED OUT ONLY IN OCTOBER. *ANOPHELES GAMBIAE* S.L. WAS THE MAIN SPECIES CAUGHT IN HLC AND INDOOR PSC IN THE DISTRICT OF**

**TAMBACOUNDA (TABLE 25).TABLE 25:** SPECIES COMPOSITION OF THE MOSQUITO ACCORDING TO THE SAMPLING METHOD IN THE DISTRICT OF **TAMBACOUNDA**

| Month | Species | HLC | | | PSC | Total |
|---|---|---|---|---|---|---|
| | | Indoors | Outdoors | Total | | |
| October | ***An. gambiae* s.l.** | **980** | **624** | **1604** | **108** | **1712** |
| | *An. funestus* s.l. | 1 | 1 | 2 | 1 | 3 |
| | *An. pharoensis* | 9 | 31 | 40 | 1 | 41 |
| | *An. nili* | 2 | 3 | 5 | 0 | 5 |
| | *An. ziemanni* | 3 | 12 | 15 | 0 | 15 |
| | *An. squamosus* | 0 | 0 | 0 | 1 | 1 |
| | *An. rufipes* | 0 | 0 | 0 | 1 | 1 |

### Human biting rate and parity rate

In October the biting rate of *Anopheles gambiae* s.l. was very high, with an average of 66.8 bites per human/night (indoor and outdoor) with similar biting rates in both villages. There was a greater indoor HBR, indicating endophagy in Wassadou which was not observed in Badi G. Nieriko. The indoor resting densities of *An. gambiae* s.l. were relatively low with an average of 5.4 females per room. This suggests exophilic behavior, with the majority having exited by morning. In both villages, the average parity rate of human biting *An. gambiae* s.l. was 78.2%.

**TABLE 26: HUMAN BITING RATES, PSC RESTING CATCH AND PARITY RATE OF *AN. GAMBIAE* S.L. IN TAMBACOUNDA DISTRICT**

| Villages | Indicators | HBR | | | PSC |
|---|---|---|---|---|---|
| | | Indoors | Outdoors | Total | |
| Wassadou | Total *An. gambiae* s.l. | 597 | 210 | 807 | 72 |
| | HBR | 99.5 BMN | 35 BMN | 67.2 BMN | 7.2 F/R |
| | PR (P/D) | 134/181 (74%) | 119/144 (82.6%) | 253/325 (77.8%) | - |
| Badi G. Nieriko | Total *An. gambiae* s.l. | 383 | 414 | 797 | 36 |
| | HBR | 63.8 BMN | 69 BMN | 66.4 BMN | 3.6 F/R |
| | PR (P/D) | 155/187 (82.9%) | 81/113 (71.7%) | 236/300 (78.7%) | - |
| Total | Total *An. gambiae* s.l. | 980 | 624 | 1 604 | 108 |
| | HBR | 81.7 BMN | 52 BMN | 66.8 BMN | 5.4 F/R |
| | PR (P/D) | 78.5 (289/368) | 77.8 (200/257) | 78.2 (489/625) | - |

HBR = human biting rate, D = number dissected, P = parous, PR = %parity rate, PRN = per room/night, BMN = Bites/man/night

## 3.3.4 DISTRICTS IN NORTH AND EAST-CENTRAL SENEGAL

For districts of the Middle Senegal River Valley and Ferlo, vector surveillance was done in the second half of October and early November. *An. gambiae* s.l. was the main species present in both HLC and indoor resting catches (Table 27).

**TABLE 27: SPECIES COMPOSITION ACCORDING TO THE SAMPLING METHOD IN NORTH AND EAST-CENTRAL DISTRICTS OF SENEGAL**

| Districts | Species | HLC | | | PSC | Total |
|---|---|---|---|---|---|---|
| | | Indoors | Outdoors | Total | | |
| Bakel | *An. gambiae* s.l. | **6** | **4** | **10** | **59** | **69** |
| | *An. ziemanni* | 1 | 0 | 1 | 0 | 1 |
| | *An rufipes* | 0 | 0 | 0 | 35 | 35 |
| Matam | *An. gambiae* s.l. | **1** | **0** | **1** | **88** | **89** |
| | *An rufipes* | 2 | 1 | 3 | 214 | 217 |
| Kanel | *An. gambiae* s.l. | **9** | **2** | **11** | **81** | **92** |
| | *An. pharoensis* | 0 | 0 | 1 | 0 | 1 |
| | *An rufipes* | 5 | 1 | 6 | 73 | 79 |
| Linguère | *An. gambiae* s.l. | **33** | **8** | **41** | **66** | **107** |
| Ranérou | *An. gambiae* s.l. | **40** | **23** | **63** | **192** | **255** |
| | *An. pharoensis* | 1 | 0 | 1 | 0 | 1 |
| | *An rufipes* | 1 | 1 | 2 | 2 | 4 |
| Podor | *An. gambiae* s.l. | **42** | **55** | **97** | **112** | **209** |
| | *An. pharoensis* | 63 | 62 | 125 | 10 | 135 |
| | *An. ziemanni* | 5 | 3 | 8 | 1 | 9 |
| | *An rufipes* | 2 | 1 | 3 | 14 | 17 |

### Human biting rate and indoor resting density

Human biting rates were generally low in north and east-central Senegal, with the mean ranging between 0.04 in Matam and 4 bites per person/night in Podor. Similarly, the mean indoor resting collection was between 3 females per house at Bakel and 9.6 in Ranérou (Table 28b).

**TABLE 28 A: HUMAN BITING RATE AND INDOOR RESTING DENSITIES FOR *ANOPHELES GAMBIAE* S.L. IN NORTHERN AND EAST-CENTRAL DISTRICTS**

| | **Bakel** | | | | **Matam** | | | | **Kanel** | | | | **Linguère** | | | | **Ranérou** | | | | **Podor** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HBR | | | PSC | HBR | | | PSC | HBR | | | PSC | HBR | | | PSC | HBR | | | PSC | HBR | | | PSC |
| | in | out | T | | in | out | T | | in | out | T | | in | out | T | | in | out | T | | in | out | T | |
| Human nights | 12 | 12 | 24 | 20 | 12 | 12 | 24 | 20 | 12 | 12 | 24 | 20 | 12 | 12 | 24 | 20 | 12 | 12 | 24 | 20 | 12 | 12 | 24 | 20 |
| *An. gambiae* s.l. | 6 | 4 | 10 | 59 | 1 | 0 | 1 | 88 | 9 | 2 | 11 | 81 | 33 | 8 | 41 | 66 | 40 | 23 | 63 | 192 | 42 | 55 | 97 | 112 |
| HBN | 0.5 | 0.3 | **0.4** | 3 | 0.1 | 0 | **0.04** | 4.4 | 0.8 | 0.2 | **0.5** | 4.1 | 2.8 | 0.7 | **1.7** | 3.3 | 3.3 | 1.9 | **2.6** | 9.6 | 3.5 | 4.6 | **4** | 5.6 |

In = indoors, out = outdoors, T = total.

**TABLE 28 B: INDOOR RESTING ANOPHELES SPECIES COMPOSITION IN THE VILLAGES OF THE NORTH AND EAST-CENTRAL DISTRICTS OF SENEGAL IN OCTOBER-NOVEMBER 2015. N = TOTAL COLLECTED**

| **Districts** | **Sites** | ***An. gambiae* s.l.** | | ***An. pharoensis*** | | ***An. rufipes*** | | ***An. ziemanni*** | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | Density | N | Density | N | Density | N | Density |
| Linguère | Barkedji | 63 | 6.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Warkhokh | 3 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kanel | Dembancane | 79 | 7.9 | 0 | 0 | 72 | 7.2 | 0 | 0 |
| | Aoure | 2 | 0.2 | 0 | 0 | 1 | 0.1 | 0 | 0 |
| Ranérou | Fourdou | 58 | 5.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Oudalaye | 134 | 13.4 | 0 | 0 | 2 | 0.2 | 0 | 0 |
| Podor | Ndiayene-Pendao | 79 | 7.9 | 9 | 0.9 | 7 | 0.7 | 1 | 0.1 |
| | Niandane | 33 | 3.3 | 1 | 0.1 | 7 | 0.7 | 0 | 0 |
| Matam | Sadel | 47 | 4.7 | 0 | 0 | 205 | 20.5 | 0 | 0 |
| | Nabadji Civol | 41 | 4.1 | 0 | 0 | 9 | 0.9 | 0 | 0 |
| Bakel | Gabou | 22 | 2.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Moudery | 37 | 3.7 | 0 | 0 | 35 | 3.5 | 0 | 0 |

**TABLE 28 C: HUMAN BITING RATE AND PARITY RATE OF *ANOPHELES GAMBIAE* S.L. AND *AN. PHAROENSIS* IN VILLAGES IN THE NORTH AND EAST-CENTRAL DISTRICTS OF SENEGAL IN OCTOBER-NOVEMBER 2015**

| Districts | Sites | *An. gambiae* s.l. | | *An. pharoensis* | |
|---|---|---|---|---|---|
| | | HBR | PR | HBR | PR |
| Linguère | Barkedji | 1.75 | 28.6 | 0 | 0 |
| | Warkhokh | 1.7 | 71.4 | 0 | 0 |
| Kanel | Dembancane | 0.9 | 100 | 0.1 | 0 |
| | Aouré | 0 | 0 | 0 | 0 |
| Ranérou | Fourdou | 1.1 | 66.7 | 0 | 0 |
| | Oudalaye | 4.2 | 46.4 | 0.1 | 0 |
| Podor | N. Pendao | 3.75 | 48.3 | 6.7 | 42.6 |
| | Niandane | 4.3 | 32.4 | 3.7 | 51.4 |
| Matam | Sadel | 0 | 0 | 0,4 | 0 |
| | Nabadji Civol | 0 | 0 | 0 | 0 |
| Bakel | Gabou | 0.2 | 0 | 0 | 0 |
| | Moudery | 0.7 | 33.3 | 0.2 | 100 |

PR = %parity rate
HBR : human biting rate (Number of bites per human per night)

### 3.3.5 NIAYES (SEPTEMBER AND NOVEMBER 2015)

Sampling of *Anopheles* populations was conducted in the villages of Diamballo and Ngadiaga by HLC and PSC and in the villages of Touba Tawfekh, Beer and Thiaye by only PSC. *Anopheles gambiae* s.l. was the only species captured in the Niayes area during September and November (Table 29). The average human biting rate was 9.3 bites per human/night, with a higher rate in Ngadiaga (17 bites per human/night) compared with Diamballo (2 bites per human/night). The indoor resting catch was relatively low in Diamballo at 6 females per room and even lower in Ngadiaga (1). In other villages, the lowest indoor resting density was recorded in Beer (0.3) whereas Thiaye (17.5) and Touba Tawfekh (22 females per room) had much higher resting densities.

Of 227 *An. gambiae* s.l. analyzed for sporozoites only one was positive (0.4%).

Species identification of *An. gambiae* s.l. (136 specimens) revealed the presence of 127 *An. arabiensis* (93.4%), 1 *An. melas* (1.52%) and 8 unspecified. The analysis of 54 blood meals taken from endophilic females including two mixed blood-meals, 30 from humans (55.5%), 11 bovine (20.4%), 11 equine (20.4%), and 4 unspecified.

**TABLE 29A: *ANOPHELES GAMBIAE* S.L. INDOOR RESTING DENSITY (IRD) AND HUMAN BITING RATE IN VILLAGES OF THE NIAYES AREA (SEPTEMBER AND NOVEMBER 2015)**

| | PSC | | | HLC | | | | |
|---|---|---|---|---|---|---|---|---|
| | Nb. rooms | *An. gambiae* s.l. | IRD | H/N | Indoor | Outdoor | Total | HBR |
| Beer | 10 | 3 | 0.3 | | | | | |
| Diambalo | 10 | 59 | 5.9 | 12 | 12 | 10 | 22 | 1.8 |
| Ngadiaga | 10 | 11 | 1.1 | 12 | 127 | 78 | 205 | 17.1 |
| Thiaye | 10 | 175 | 17.5 | | | | | |
| Touba Tawfekh | 10 | 220 | 22 | | | | | |
| Total | 50 | 468 | 9.4 | 24 | 139 | 88 | 227 | 9.4 |

### 3.3.6 FLOODED AREAS IN THE SUBURBS OF DAKAR (PIKINE AND GUEDIAWAYE)

In this area, vector susceptibility to insecticides and mosquito species composition was monitored. All 208 identified specimens were identified by PCR as being *An. arabiensis* (96 in Pikine and 112 Guédiawaye).

### 3.3.7 GUINGUINÉO DISTRICT (OCTOBER 2015)

The results show that *An. gambiae* s.l. was the only species complex collected resting indoors and was the main species caught biting humans in October. Human biting densities were low (less than 1 bite per human/night), while the indoor resting density was slightly higher at 3.6 females per room.

### 3.3.8 RICHARD-TOLL (OCTOBER 2015)

There were no HLC collections in Richard-Toll. In total, 388 female *An. gambiae* s.l., 18 *An. funestus* s.l. and 19 *An. pharoensis* were collected resting indoors in 10 villages, with an average of 3.9 females per room/night.

## 3.4 SUSCEPTIBILITY OF MALARIA VECTORS TO INSECTICIDES WITH IMPREGNATED PAPERS

The results of WHO tube assays (Table 30a) show resistance of *Anopheles gambiae* s.l. to all five pyrethroid insecticides tested in all districts, except in rare cases where susceptibility was recorded in Koungheul (alpha-cypermethrin and cyfluthrin) and Richard-Toll (lambda-cyhalothrin). The same trend of widespread resistance is recorded for organochlorines, although in some cases susceptibility was noted with dieldrin (Fatick, Koungheul and Koumpentoum). In the Niayes area where *An. arabiensis* is predominant, the kdr west mutation was more frequent than the kdr east mutation (Table 30b).

For organophosphates the vector populations are largely susceptible, although there are worrying signs of resistance to pirimiphos-methyl in Koungheul where mortality was 95.2%. This should be investigated further. There was also resistance to fenitrothion (Guédiawaye and Niayes) and malathion (Pikine) recorded. *An. gambiae* also showed susceptibility to carbamates in all districts except in Ndoffane and Niayes where early signs of resistance were observed and in the suburbs of Dakar (Pikine and Guediawaye).

In Malam Hodar, Ndoffane, Guingueneo and Richard Toll not all insecticides were tested due to lack of larvae following heavy rainfall. We recommend that future resistance testing should focus only on insecticides that can be used for IRS and LLIN.

**TABLE 30A : SUSCEPTIBILITY STATUS OF *AN. GAMBIAE* S.L. TO PYRETHROID, CARBAMATE, ORGANOPHOSPHATE AND ORGANOCHLORINE INSECTICIDES (N = 100 FOR ALL SITES/INSECTICIDE)**

| IRS status | Districts | Delta-methrin 0.05% | Lambda-cyhalothrin 0.05% | Permethrin 0.75% | Alpha cypermethrin 0.1% | Cyfluthrin 0.15% | DDT 4% | Dieldrin 4% | Pirimiphos-methyl 1% | Fenitro-thion 1% | Malathion 5% | Bendiocarb 0.1% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **IRS 5 years** | **Koumpentoum** | 63 | 56 | 77 | 84 | 71 | 74 | 98 | 100 | 100 | 100 | 99 |
| **IRS 5 years** | **Malem Hodar** | 60 | - | 47 | - | - | 65 | - | 100 | 100 | - | 100 |
| **IRS 4 years** | **Koungheul** | 85 | 98 | 92 | 100 | 98 | 91 | 100 | 95 | 100 | 100 | 100 |
| **IRS 1 year** | **Nioro** | 83 | 82 | 64 | 97 | 77 | 79 | 93 | 100 | 100 | 100 | 100 |
| **Former IRS** | **Velingara** | 88 | 77 | 92 | 90 | 65 | 83 | 92 | 99,3 | 100 | 100 | 99 |
| **NO IRS** | **Fatick** | 77 | 88 | 80 | 84 | 91 | 53 | 99 | 100 | 100 | 100 | 100 |
| | **Bambey** | 86 | 85 | 85 | 81 | 84 | 70 | 97 | 100 | 100 | 100 | 100 |
| | **Niakhar** | 90 | 94 | 94 | 92 | 96 | 56 | 94 | 100 | 100 | 100 | 100 |
| | **Ndoffane** | 88 | - | 60 | - | - | 43 | - | 100 | - | - | 96 |
| | **Mbour** | 69 | 91 | 89 | 86 | 70 | 36 | 92 | 100 | 99 | 100 | 100 |
| | **Pikine** | 62 | 23 | 22 | 64 | 25 | 1 | 14 | 100 | 100 | 95 | 63 |
| | **Guediawaye** | 47 | 17 | 3 | 43 | 32 | 1 | 32 | 100 | 74 | 100 | 35 |
| | **Niayes** | 52 | 64 | 38 | 68 | 45 | 28 | 49 | 99,5 | 95 | 100 | 90 |
| | **Richard Toll** | 78 | 100 | 23 | - | - | 54 | - | - | 100 | - | - |
| | **Guingueneo** | 95 | - | 84 | - | - | 64 | - | - | 100 | - | - |

**TABLE 30B: KDR WEST AND EAST FREQUENCIES FOR *AN. ARABIENSIS* (125) AND ONE *AN. MELAS* (1) WHICH SURVIVED SUSCEPTIBILITY TESTS TO DDT OR PYRETHROIDS IN TWO VILLAGES OF THE THE NIAYES AREA**

| Niayes area villages | Kdr east | | | | Kdr west | | | |
|---|---|---|---|---|---|---|---|---|
| | RR | SR | SS | Total | RR | SR | SS | Total |
| **Mont Rolland** | 13 (20.6) | 3 (4.8) | 1 | **17** | 22 (34.9) | 23 (36.5) | 1 | **46** |
| **Thiaye*** | 7 (11.3) | 2 (3.2) | 3 | **12** | 34 (54.8) | 16 (25.8) | 0 | **50** |
| **Total** | **20 (16)** | **5 (4)** | **4** | **29** | **56 (44.8)** | **39** | **1** | **96** |

* 1 female of An. melas

## 3.5 SUSCEPTIBILITY OF MALARIA VECTORS TO INSECTICIDES WITH CDC BOTTLE TEST

Results of the tests are shown in Table 31. WHO tube tests and bottle bioassays were done during different months and this may partially explain the difference in results for some insecticides between the two test types. In addition, it will be important to carry out PCR identification to confirm the species composition of each test. Furthermore, pirimiphos-methyl is known to be unstable when used in bottles so the WHO results are likely more reliable for this compound. In Kédougou, susceptibility tests with CDC bottle bioassays were performed with three insecticides (DDT, permethrin and deltamethrin). *An. gambiae* s.l. were resistant to DDT with 35.1% mortality (n = 91) and permethrin with 75.2% mortality (n = 97). Suspected resistance was noted for deltamethrin with 97% mortality (n = 100).

Bottle bioassays with synergists indicated the involvement of mixed function oxidases in Richard Toll and Rufisque against DDT and permethrin, although full susceptibility was not restored (Table 32).

**TABLE 31: SUSCEPTIBILITY STATUS OF *AN. GAMBIAE* S.L. WITH CDC BOTTLE TESTS**

| | Districts | Deltamethrin 12.5µl/Btl | Permethrin 21.5µl/Btl | DDT 100µl/Btl | Pirimiphos methyl 20µl/Btl | Bendiocarb 12µl/Btl |
|---|---|---|---|---|---|---|
| IRS 5 years | Koumpentoum | 100 (105) | 96 (109) | 96 (101) | - | 100 (106) |
| IRS 5 years | Malem Hodar | 100 (100) | - | 83 (108) | - | 100 (100) |
| IRS 4 years | Koungheul | 98 (108) | 99 (216) | 97 (2016) | 99 (105) | 100 (105) |
| IRS 1 year | Nioro | 100 (110) | 98 (102) | 92 (103) | - | 100 (105) |
| No IRS | Pikine | 88 (106) | 87 (101) | 36 (105) | 56 (106) | 100 (106) |
| | Guediawaye | 93 (107) | 87 (105) | 2 (101) | 61 (98) | 100 (96) |
| | Kedougou | 98 (62) | 86 (97) | 36 (66) | - | - |
| | Richard Toll | 91 (106) | 84 (110) | 25 (113) | 99 (104) | 100 (110) |
| | Guinguineo | 97 (108) | 96 (98) | 65 (105) | - | 100 (108) |
| | Rufisque | 95 (102) | 71 (112) | 15 (117) | - | 100 (100) |

() : Number of mosquitoes exposed

**TABLE 32: SYNERGIST BOTTLE ASSAY TO DETERMINE THE INVOLVEMENT OF METABOLIC MECHANISMS IN VECTOR RESISTANCE TO DDT AND PERMETHRIN**

| IRS status | Districts | DDT | | Permethrin | |
|---|---|---|---|---|---|
| | | DDT only | DDT + EA | Permethrin only | Permethrin + PBO |
| IRS | Koumpentoum | 96 (101) | 99 (102) | 96 (109) | - |

| | | | | | |
|---|---|---|---|---|---|
| NON-IRS | Richard Toll | 25 (113) | 67 (88) | 84 (110) | 96 (71) |
| | Rufisque | 15 (117) | 27 (98) | 71 (112) | 91 (106) |

# 4. CONCLUSION

This report presents results monitoring the residual effectiveness of the spray campaign and entomological surveillance in Senegal during the rainy season (July-November 2015). Pirimiphos-methyl IRS lasted for most of the malaria transmission period. It should be noted that due to the lower efficacy six months post treatment, the start of the IRS campaign could be moved to July in efforts to cover the entire transmission period of July to November. The residual duration of bendiocarb applied in Nioro was very low. However, the residual duration of pirimiphos-methyl in the same area was also very low compared to all other districts. This may indicate a problem with spray implementation or the specific conditions in this area result in shorter residual performance (e.g. mud composition).

In general, the population density of malaria vectors was low in the districts of North and Central Senegal including districts under IRS treatment. The biting rates were considerably higher in the south of the country in Velingara, Tambacounda and Kedougou. It was also inferred that in the more arid areas of North and Central Senegal populations of vectors show tended towards endophily unlike those in the South, which seemed more exophilic when comparing indoor biting rates to indoor resting densities via PSCs.

Susceptibility tests of *Anopheles gambiae* s.l. to insecticides generally confirm widespread susceptibility to organophosphates and carbamates with resistance to pyrethroids and organochlorines. Resistance is higher in flooded areas in the suburbs of Dakar and in the Niayes area where pesticides are used to protect vegetables (market gardening). Processing of laboratory samples is proceeding and results will be presented in a supplementary document in early 2017.

# ANNEX A:
# FIELD VISITS CARRIED OUT IN THE RAINY SEASON OF JULY-NOVEMBER 2015

| N° | Districts | Dates | Equipes | Véhicules |
|---|---|---|---|---|
| 1 | Malem Hodar - Koungheul Koumpentoum | 29 Juillet – 07 Août 2015 | M D Sy, C Lo & I Thiam | 03 NU IT 159 |
| 2 | Nioro - Kédougou | 30 Juillet – 08 Août 2015 | M Diagne, M N Faye & B Ndiouck | 03 NU IT 154 |
| 3 | Malem Hodar –Kaffrine Koumpentoum | 21 Aout - 05 Septembre 2015 | M D Sy, C Lo & I Thiam | 03 NU IT 159 |
| 4 | Koungheul - Vélingara | 21 Aout - 05 Septembre 2015 | M Diagne, M N Faye, A K Dia & B Ndiouck | 03 NU IT 154 |
| 5 | Nioro - Ndoffane | 24 Aout - 06 Septembre 2015 | M W Senghor, Y Coulibaly, A Y Ndiaye & O Niang | 03 NU IT 165 |
| 6 | Koumpentoum | 11 au 20 Septembre 2015 | M D Sy, C Lo & I Thiam | 03 NU IT 159 |
| 7 | Koungheul | 11 au 20 Septembre 2015 | M Diagne, M N Faye, A Y Ndiaye & B Ndiouck | 03 NU IT 154 |
| 8 | Malem Hodar | 11 au 20 Septembre 2015 | M W Senghor, Y Coulibaly, E Diouf & O Niang | 03 NU IT 165 |
| 9 | Zones inondées et Niayes | 09- 20 Septembre 2015 | A Konaté, PM Fall, A Amblat, OK Guèye, B Niang & MF Tall | DK 0891 EP 96 |
| 10 | Nioro | 28 Sept. - 03 Oct 2015 | M D Sy, C Lo, A Y Ndiaye & I Thiam | 03 NU IT 159 |
| 11 | Koumpentoum - Koungheul | 12 au 23 Octobre 2015 | M D Sy, C Lo, A K Dia & I Thiam | 03 NU IT 159 |
| 12 | Kédougou - Tambacounda | 05 – 15 Octobre 2015 | M Diagne, M N Faye, M Fall & B Ndiouck | 03 NU IT 154 |
| 13 | Guinguinéo - Richard-Toll | 12 – 24 Octobre 2015 | M W Senghor, Y Coulibaly, E Diouf & O Niang | DK 4561 AC |
| 14 | Malem Hodar - Kaffrine | 28 Oct. - 04 Nov. 2015 | M W Senghor, A K Dia & O Niang | DK 4561 AC |
| 15 | Nioro - Ndoffane | 29 Oct - 05 Nov. 2015 | M D Sy & I Thiam | 03 NU IT 159 |
| 16 | Vélingara | 28 Oct. – 06 Novembre 2015 | M Diagne & B Ndiouck | 03 NU IT 154 |
| 17 | Zones inondées et Niayes | 15 Octobre – 07 Nov. 2015 | A Konaté, PM Fall, AA Amblat, OK Guèye, B Niang & MF Tall | DK 0891 EP 96 |
| 18 | Koumpentoum - Koungheul | 18-30 Novembre 2016 | M D Sy & I Thiam | 03 NU IT 159 |
| 19 | Malem Hodar - Nioro | 18-30 Novembre 2016 | M W Senghor, M N Faye & O Niang | DK 4561 AC |