

President's Malaria Initiative Country Insecticide Susceptibility Summaries

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Introduction

This report summarizes the insecticide susceptibility data that has been collected by the President's Malaria Initiative (PMI) as of the end of July 2016. The report includes data collected by PMI entomologists and contractors, as well as data collected in collaboration with partner-country universities or National Malaria Control Programs (NMCPs). In some cases data collected by other partners is also cited.

For each PMI country, background information on vector control interventions, particularly PMI-supported indoor residual spraying (IRS), is summarized. A note on the data collected and conclusions follow. Summary tables of mosquito mortality data are also included for each country. Mosquitoes were tested against pyrethroids, carbamates, dichlorodiphenyltrichloroethane (DDT), and organophosphates (OPs).

Unless otherwise noted, WHO tube bioassays were conducted, and percent mortalities 24 hours after exposure were recorded for 2 to 5-day-old female mosquitoes reared from field-collected larvae. In all tables, the first number is percent mortality, and the number of mosquitoes tested in is parentheses.

Interpretation of WHO susceptibility data is based on the WHO Test Procedures for Insecticide Resistance Monitoring in Malaria Vector Mosquitoes, April 2013. Color coding is used in the country tables to facilitate interpretation: susceptible is shaded green (98-100% mortality); suspected resistance requiring confirmation is yellow (90-97%); resistance that does not require further confirmation if appropriate methods were used is orange (80-90%) or red (<80%). If data on resistance mechanisms, resistance intensity, and/or synergist assays was collected, it is also included.

Much of the data presented here should be confirmed with additional testing, but overall this document provides valuable information regarding trends in insecticide resistance in PMI countries.

OVERALL TRENDS

There are some broad trends across Africa that can be summarized, although every country context differs, and there is a range of resistance within countries.

West Africa *An. gambiae* s.l. (Benin, Ghana, Guinea, Liberia, Mali, Nigeria, Senegal):

There is generally high resistance to pyrethroids and DDT. Resistance to carbamates ranges from 100% susceptibility to moderate resistance. There is probable to moderate resistance developing to fenitrothion and malathion OPs, but generally susceptibility to pirimiphos-methyl. Data have shown emerging resistance to pirimiphos-methyl in Nigeria and Ghana; however, this requires further testing to confirm that it is not due to problems with insecticide stability. Intensity data report only slight increases in susceptibility to pyrethroids across increasing concentrations. Where available, data on synergist testing show only partial restoration in susceptibility to pyrethroids with pre-exposure.

East Africa *An. gambiae* s.l. (Ethiopia, Kenya, Tanzania, Uganda):

An. arabiensis and *An. gambiae* s.s. are both major vectors and not always distinguished by molecular methods, so there is a large variation in resistance reports. In general, resistance is lower than in West Africa. Pyrethroid and DDT resistance ranges from none to very high. Where species are differentiated (Kenya), *An. arabiensis* has lower pyrethroid resistance and is susceptible to DDT. Carbamate resistance varies from susceptible to moderate resistance. *An. gambiae* s.l. is mainly susceptible to OPs, with the exception of moderate resistance to malathion or fenitrothion in a few sites, as well as confirmed resistance to pirimiphos-methyl from Tanzania.

Central Africa *An. gambiae* s.l. (Burundi, DRC, Rwanda):

There are reports of very high pyrethroid and DDT resistance across all countries, although there are some sites that have lower or only probable resistance. There is emerging carbamate resistance, although many sites still have susceptibility. There is 100% susceptibility to OPs. Synergist testing has been performed in DRC, Rwanda, and has demonstrated partial or major restoration of susceptibility to pyrethroids with pre-exposure to PBO.

Southern Africa *An. gambiae* s.l. (Angola, Madagascar, Malawi, Mozambique, Zambia, Zimbabwe):

Within most countries, resistance to pyrethroids and DDT ranges from 100% susceptibility to very high resistance. This could be due to differences in species composition, as in East Africa. There is emerging or moderate carbamate resistance in most countries. There is 100%

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susceptibility to OPs, with the exception of possible resistance to fenitrothion at a few sites in Madagascar.

An. funestus (Kenya, Madagascar, Malawi, Mozambique, Zambia, Zimbabwe):

In general, *An. funestus* in East and Southern Africa are highly resistant to pyrethroids (with the exception of Madagascar), moderately to highly resistant to carbamates, and susceptible to DDT and OPs.

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ANGOLA

PMI-supported IRS was conducted in Angola from 2010-2014 and after IRS was discontinued, entomological monitoring continued through 2016. Throughout the four years of spraying, IRS with deltamethrin was carried out in Huambo, Huila, and Cunene. In 2014 (Round 10), PMI only supported IRS in Huambo, but with continued entomological monitoring in former IRS provinces (Cunene and Huila). Pyrethroids were the only insecticides used for IRS. From 2015-2016, entomological monitoring remained a focus in order to continue tracking trends in insecticide resistance. In 2015, larvae were collected from nine provinces across Angola and tested against 5 insecticides using WHO tube assay.

COMMENTS ON DATA:

An. coustani and *An. gambiae* s.l. mosquitoes were tested.

For 2015, mosquitoes used in assays were presumed to be *An. gambiae* s.l.; however, in many locations, molecular testing showed that a variety of *Anopheles* species were tested. The majority were secondary or non-vector species, although a percentage were *An. arabiensis* and *An. gambiae* s.l. In most surveillance sites, *An. funestus* s.l. is more common in adult surveillance collections than *An. gambiae* s.l.

CONCLUSIONS:

- Recent data shows full susceptibility to pirimiphos-methyl, with possible emerging resistance to fenitrothion. While data supporting the emergence of resistance to carbamates has been noted in the past, recent tests have confirmed full susceptibility in *An. gambiae* s.l.
- DDT has not been tested on *An. gambiae* s.l. by PMI to date.
- Emerging resistance to pyrethroids is likely widespread.

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An. gambiae s.l. mosquitoes were tested unless otherwise noted. Data for *An. coustani* are indicated in purple italic with an asterisk, e.g., *100(100)**. 2014 data from Huambo is from Bailundo Municipality.

Province	Deltamethrin 0.05%						Lambdacyhalothrin 0.05%	
	2010	2011	2012	2013	2014	2015	2009	2015
Huambo	<i>100(59)*</i>	<i>94 (30)*</i>	94(16); <i>100(80)*</i>	<i>100(110)*</i>	100 (100)	97 (100)	<i>94(40)*</i>	N/A
Huila	<i>100(20)*</i>	92 (15); <i>100(20)*</i>	94 (35)	94.7 (100)		100 (100)		99 (120)
Cunene		93.3(15)	97.5 (80)			100 (100)		91 (100)
Benguela						96 (100)		N/A
Luanda						97 (100)		100 (20)
Malanje						92 (100)		98 (75)
Namibe						93 (100)		100 (60)
Uige						98 (100)		100 (100)
Zaire						96 (100)		N/A

Province	Bendiocarb 0.1%					
	2010	2011	2012	2013	2014	2015
Huambo	<i>95(60)*</i>	<i>97 (24)*</i>	<i>100(20)*</i>	<i>100(89)*</i>	100 (100)	100 (100)
Huila		90 (30)	<i>100(40)*</i>	100 (100)		100 (100)
Cunene						100 (100)
Benguela						100 (100)
Luanda						100 (100)
Malanje						100 (100)
Namibe						100 (100)
Uige						100 (100)
Zaire						100 (30)

Province	Fenitrothion 1%				Pirimiphos-methyl 0.25%
	2012	2013	2014	2015	2015
Huambo	<i>100 (60)*</i>	<i>100 (50)*</i>	100 (100)	N/A	100 (100)
Huila		100 (100)		98 (100)	98 (100)
Cunene				100 (100)	100 (100)
Namibe				97 (100)	99 (100)
Benguela					100 (100)
Luanda					100 (100)
Malanje					100 (100)

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BENIN

PMI is the sole supporter of IRS in Benin. PMI IRS support to Benin began in 2008. From 2008-2010, PMI-supported IRS occurred in the department of Oueme (4 communes) with carbamates. In 2011, IRS was discontinued in Oueme and initiated in the department of Atacora (7 communes, increased to 9 in 2012). For 2011-12, carbamates were used for IRS, and in 2013 IRS was shifted to a carbamate in 4 districts and organophosphate in 5 districts. For 2014 - 2016, organophosphates were used to spray all 9 communes in Atacora.

COMMENTS ON DATA:

Susceptibility data were collected in collaboration with Centre de Recherche Entomologique de Cotonou (CREC).

An. gambiae s.l. mosquitoes were tested. Data for *kdr* and *ace-1* allele frequencies were determined in 2011 and 2012.

CONCLUSIONS:

- *An. gambiae* s.l. in both Oueme and Atacora show a high prevalence of the *kdr* mutation, as well as phenotypic resistance to DDT and pyrethroids.
- There is resistance to carbamates, particularly in Atacora where the *ace-1* mutation is present; carbamates have not been used for IRS since 2013.
- Organophosphates have been tested in Atacora, and *An. gambiae* s.l. still shows full susceptibility to pirimiphos-methyl.

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Atacora Region: Pyrethroids and DDT. For *kdr* frequencies, unbolded numbers are data from 2012. Pyrethroids and DDT are not used for IRS, and have not been tested since 2012.

sites	kdr freq	Deltamethrin 0.05%			Permethrin 0.75%		DDT 4%	
		2010	2011	2012	2010	2011	2010	2011
Pehunco	0.85	27 (124)		68 (74)	15 (103)		17 (54)	
Kouande	0.8	31 (147)	87 (90)	49 (67)	6 (108)	62 (76)	14 (63)	26 (90)
Materi	0.8	31 (73)	91 (65)		6 (108)	45 (96)	12 (65)	27 (97)
Tanguieta	0.8	31 (93)	93 (71)	46 (72)	6 (73)	32 (118)	13 (39)	23 (88)
Natintingou	0.82	31 (90)	80 (91)	57 (21)	13 (71)	31 (98)	12 (65)	27 (91)
Copargo	0.81							

Atacora Region: Carbamates. For *ace-1* frequency, unbolded indicates 2012 frequency, **bold** indicates **2014** frequency.

site	ace-1 freq	Bendiocarb 0.1 %				Propoxur 0.1%	
		2010-12	2013	2014	2015	2012	2014
Pehunco	0.15	79 (101)		80 (116)		80 (64)	77 (79)
Kouande	0.04	79 (90)	80 (99)			90 (60)	
Materi	0.03	59 (73)			91 (88)	89 (70)	
Tanguieta	0.1	63 (106)	72 (115)		94 (90)	88 (59)	
Natintingou	0.09	62 (84)	66 (73)		87(93)	91 (62)	
Copargo	0.04	90 (69)					
Boukoumbe	N/A				89 (91)		

Atacora Region: Organophosphates. For *ace-1* frequency, unbolded indicates 2012 frequency, **bold** indicates **2014** frequency.

site	ace-1 freq	Fenitrothion 1%			Pirimiphos-methyl 0.25%			
		2012	2013	2014	2012	2013	2014	2015
Pehunco	0.15	90 (89)		92 (101)	99 (89)		99 (103)	
Kouande	0.04	88 (82)			100 (81)			
Materi	0.03	95 (96)			100 (72)			100 (79)
Tanguieta	0.1	84 (49)	83.5 (97)		100 (90)	100 (89)		99 (92)
Natintingou	0.09	95 (70)	87 (67)		100 (58)	99 (88)		99 (91)
Copargo	0.04				100 (79)			
Boukoumbe	N/A							100 (90)

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Oueme Region: WHO tube assays for *An. gambiae* s.l., pyrethroids and DDT. IRS has not been conducted in Oueme since 2011, because the length of the malaria season in that region requires two rounds of spraying. *Kdr* and *ace-1* gene frequencies are from 2011.

site	kdr mutation	Deltamethrin 0.05%			Permethrin 0.75%			DDT 4%		
		2009	2010	2011	2009	2010	2011	2009	2010	2011
Adjohoun	0.8	100(100)	14(28)	87(84)	97.1(100)	11(53)	75 (63)	64(100)	0(35)	5(19)
Dangbo	0.83	100(100)	74(84)	88(42)	83.8(100)	17(65)	65(20)	45(100)	2.5(48)	1(98)
Misserete	0.86	100(100)	70(54)	97(112)	90.8(100)	16(62)	66(93)	39(100)	5(77)	17(65)
Seme	0.86		85(99)	80(81)		14(99)	85(48)		13(102)	78(46)

Oueme Region: WHO tube assays for *An. gambiae* s.l., carbamates.

site	ace-1 mutation	Bendiocarb 0.1%		
		2009	2010	2011
Adjohoun	0	100(100)	100(34)	90(89)
Dangbo	0	100(100)	100(45)	100(40)
Misserete	0	100(100)	99(100)	100(112)
Seme	0		100(49)	100(49)

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BURUNDI

PMI does not support IRS in Burundi. However, Swiss TPH and the Public Health Institute have funded IRS in the sentinel site of Kiremba since 2010, using deltamethrin. USAID malaria funding does support entomological monitoring in Burundi.

COMMENTS ON DATA:

An. gambiae s.l. mosquitoes were tested, March-June 2014.

CONCLUSIONS:

- Insecticide susceptibility tests have been conducted in 6 provinces
- Between provinces, resistance to pyrethroids and DDT ranges from susceptible to highly resistant.
- *An. gambiae* s.l. populations are still mainly susceptible to carbamates
- Malathion showed 100% susceptibility across all sites.
- Organophosphates have not been tested by PMI

Province	Site	Deltamethrin 0.05% 2014	Permethrin 0.75% 2014	DDT 4% 2014	Bendiocarb 0.1% 2014	Malathion 5% 2014
Bubanza	Mpanda	89 (100)	94 (99)	97 (100)	89 (100)	100 (100)
Ngozi	Kiremba	83 (100)	56 (100)	80 (100)	100 (100)	100 (100)
Muyinga	Gashoho	92 (100)		16 (100)	99 (99)	100 (99)
Cankuzo	Cankuzo	53 (100)		3 (100)	95 (100)	100 (100)
Cibitoke	Mabayi	100 (100)		32 (100)	100 (100)	100 (100)
Rutana	Gihofi	85 (100)		85 (100)	100 (100)	100 (100)

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DRC

PMI has worked in 70 health zones in four provinces in DRC since FY 2011, and has since expanded to 138 zones in 5 provinces. IRS is listed in the NMCP Strategic Plan, but a detailed IRS plan has not been developed for DRC. Currently, at least one mining company (Tenke Fungurume Mining) conducts yearly IRS in ~36,000 houses in Fungurume Health Zone, Katanga Province. PMI does not currently support IRS in DRC, but continued entomological monitoring in 7 sites for 2015.

COMMENTS ON DATA:

Data from 2012 were collected by RTI International, total number of mosquitoes tested was not reported. Data from 2013-2015 were collected by Abt Associates. For all years, *An. gambiae* s.l. were tested by WHO tube assay.

CONCLUSIONS:

- Insecticide susceptibility tests have been conducted at sites in 7 provinces.
- There is widespread resistance to DDT and permethrin, but only low levels of resistance against deltamethrin and lambda-cyhalothrin.
- There is full susceptibility to carbamates and organophosphates.
- Assays testing permethrin with a PBO synergist show widespread increased susceptibility.

DDT:

Province	District	Site	DDT 4%			
			2012	2013	2014	2015
Sankuru	Lodja	Lodja	40		13 (100)	8 (100)
Kasai Oriental		Mbuji Mayi	46			
Kasai Central	Kananga	Tshikaji	50		13 (100)	
Kasai Central	Kananga	Mikalayi			42 (100)	15 (100)
Tshopo	Kisangani	Kabondo	54	40 (100)	17 (100)	37 (100)
Haut Katanga	Kapolowe	Kapolowe			45 (80)	37 (100)
Tanganyika		Kalemie				33 (100)
Kinshasa	Tshangu	Kingasani			17 (100)	7.5 (80)

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Pyrethroids:

Province	District	Site	Deltamethrin 0.05%				Permethrin 0.75%			Lambdacyhalothrin 0.05%
			2012	2013	2014	2015	2012	2013	2015	2012
Sankuru	Lodja	Lodja	100	96 (100)	98 (100)	100 (100)	64	49 (100)	68 (100)	100
Kasai Oriental		Mbuji Mayi	100				28			100
Kasai Central	Kananga	Tshikaji	85	92 (100)	98 (100)		56	45 (100)		100
Kasai Central	Kananga	Mikalayi			99 (100)	100 (100)			30 (100)	
Tshopo	Kisangani	Kabondo		100 (100)	99 (100)	85 (100)		27 (100)	52 (100)	
Haut Katanga	Kapolowe	Kapolowe	85	95 (25)	99 (80)	100 (80)	66	39 (25)	53 (80)	100
Tanganyika		Kalemie				100 (100)			55 (100)	
Kinshasa	Tshangu	Kingasani			99 (100)	97 (80)			91 (80)	
South Kivu		Katana	96			98 (100)	100		92 (100)	97

Carbamates and Organophosphates:

Province	District	Site	Bendiocarb 0.1%				Malathion 5%	Fenitrothion 1%	Pirimiphos-methyl 0.1%	
			2012	2013	2014	2015	2012	2013	2014	2015
Sankuru	Lodja	Lodja	100	100 (100)	100 (100)	100(100)	100	100 (100)	100 (100)	100 (100)
Kasai Oriental		Mbuji Mayi	100				100			
Kasai Central	Kananga	Tshikaji	100	100 (100)	100 (100)		100	100 (100)	100 (100)	
Kasai Central	Kananga	Mikalayi			100 (100)	100 (100)			100 (100)	100 (100)
Tshopo	Kisangani	Kabondo		100 (100)	100 (100)	100 (100)		100 (100)	100 (100)	100 (100)
Haut Katanga	Kapolowe	Kapolowe	100	100 (25)	100 (80)	100 (80)	100	100 (25)	100 (80)	100 (80)
Tanganyika		Kalemie				100 (100)				100 (100)
Kinshasa	Tshangu	Kingasani			100 (100)	100 (80)			100 (100)	100 (80)
South Kivu		Katana				100 (100)				100 (100)

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PBO synergist testing 2015: Data are percent mortality

District	PBO synergist testing 2015	
	Permethrin 0.75%	Permethrin + PBO
KABONDO	62 (100)	86 (100)
KALEMIE	94 (100)	96 (100)
KAPOLOWE	53 (100)	100 (100)
LODJA	79 (100)	100 (100)
MIKALAYI	30 (100)	100 (100)
KINGASANI	92 (100)	99 (100)
KATANA	99 (100)	100 (100)

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ETHIOPIA

PMI contributes to the Government of Ethiopia-led IRS operation, and has been supporting districts to varying degrees based on technical/financial capacity. PMI IRS support to Ethiopia began in 2008. PMI's focus was originally Oromia Regional State, which, as the largest of Ethiopia's nine states, comprises a third of the country's territory and population; since 2011 support for IRS-related trainings and workshops, as well as entomological monitoring activities, has expanded to a national level. In 2008, PMI-supported IRS occurred in 19 districts in Oromia. By 2011 the number of PMI-supported districts increased to 50. In 2012-2015, PMI fully supported 36 districts, and an additional 24 "graduated districts" that transitioned to minimal technical assistance.

In 2011-2012, Ethiopia sprayed 2 rounds per year, the first with pyrethroids and the second with carbamates. In 2013-2014, only carbamates were used. In 2015, both carbamates (29 districts across 6 zones) and organophosphates (8 districts across 6 zones) were used in IRS.

COMMENTS ON DATA:

Susceptibility data was collected by PMI in collaboration with Ethiopian universities. *An. gambiae* s.l. mosquitoes were tested with WHO tube assays.

CDC bottle bioassays in 2014 showed a range of 5-10X DDT resistance, and 1X-10X pyrethroid resistance in Dugda, Adama, Bako Tibe, and Wondogenet (Oromia). In Amhara, bottle bioassays showed 10X DDT resistance and no pyrethroid resistance. PBO synergist assays were performed in Dugda, and implicated mixed-function oxidases in pyrethroid resistance, but not DDT. Bottle bioassays showed 100% susceptibility to carbamates, with the exception of 2X resistance in Wondongenet. In 2015, 10x permethrin and deltamethrin resulted in 100% mortality in Abedogora and Chewaka districts. Pre-exposure to PBO restored susceptibility to permethrin and deltamethrin in Dugda and Halaba districts.

CONCLUSIONS:

- There is high pyrethroid and DDT resistance in all tested sites, with varying intensity of resistance.
- There was near complete susceptibility to propoxur; two sites, Omo Nada and Bahirdar showed resistance to bendiocarb.
- For organophosphates, there is resistance or probable resistance to malathion in nearly all tested sites, but 100% susceptibility to fenitrothion and pirimiphos-methyl.

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WHO tube assay for carbamates and DDT, *An. gambiae* s.l., 2012-2015; Region and zone locations shown for reference.

Region	Zone	District	Site	Bendiocarb 0.1%				Propoxur 0.1%				DDT 4%					
				2012	2013	2014	2015	2012	2013	2014	2015	2012	2013	2014	2015		
Oromia	East	Gida Ayana	Gutin					100									
	Wollega							(100)									
Oromia	West	Nejo Town						100									
	Wollega							(100)									
Oromia	Kelem	Dale Sedi	Aweitu-					100									
	Welega		Gendosa					(100)									
Oromia	East	Gobu Sayo	Gambella	100				100									
	Wollega		Tere	(75)				(100)									
Oromia	West	Ilu Gelan	Siba	97				98									
	Shoa		Biche	(150)				(100)									
Oromia	Jimma	Oma Nada	Asendabo	94	92	86	95	99(205)	98	100	100	4	9	7	4		
				(205)	(100)	(88)	(100)		(100)	(100)	(100)	(103)	(100)	(88)	(100)		
SNNPR	Halaba	Halaba	Halaba	98				99			100	0			25		
			Town	(100)				(100)			(102)	(100)			(100)		
Oromia	Arsi	Zeway-	Shenen	100	100	100	100	100	100	100	100	13	26	6			
		Dugda		(100)	(100)	(101)	(100)	(100)	(100)	(101)	(100)	(100)	(100)	(97)			
Oromia	Illubabor	Chewaka	Chewaka	90	100	100	100	96	100	100	100	3	22	6	14		
				(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(104)		
Amhara	Bahirdar	Bahirdar	Zenzlima-	87	75	87	87	100	96	99	99	6	16	9	11		
			Robit	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(75)	(93)		
Oromia		Ameya			100				100				2				
					(100)				(100)				(100)				
Oromia		Wonchi			100				100				4				
					(100)				(100)				(100)				
Oromia		Humbo	Abaya		75				75				8				
					(275)				(175)				(100)				
Tigray		Alamata				96	100			98	100			25	40		
						(100)	(100)			(100)	(100)			(100)	(75)		
Afar		Amibara				100	100			100	100			19	48		
						(105)	(100)			(102)	(102)			(101)	(100)		
Gambela		Gambela				92	100			100	100			13	24		
						(88)	(100)			(88)	(100)			(88)	(100)		

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WHO tube assay for pyrethroids, *An. gambiae* s.l., 2012-2015.

District	Site	Deltamethrin 0.05%				Permethrin 0.75%				Lambdacyhalothrin 0.05%				Etofenprox 0.5%				Alphacypermethrin 0.5%				
		2012	2013	2014	2015	2012	2013	2014	2015	2012	2013	2014	2015	2012	2013	2014	2015	2012	2013	2014	2015	
Gida	Gutin	42																				
Ayana		(200)																				
Nejo Town		61																				
		(100)																				
Dale Sedi	Aweitu-	52																				
	Gendosa	(100)																				
Gobu	Gambella	16																				
Sayo	Tere	(100)																				
Ilu Gelan	Siba	11																				
	Biche	(100)																				
Oma Nada	Asendabo	11	26	42	32	11	22	16	22	26	15	39	9	9		55	50	25		35	4	
		(215)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(105)	(100)	(100)	(100)	(115)		(100)	(100)	(105)		(100)	(100)	
Halaba	Halaba	1			43				25				21								16	
	Town	(100)			(107)				(105)				(103)								(105)	
Zeway-	Shenen	27	36	11	32			3	13			4			20	29				32	5	
Dugda		(100)	(100)	(196)	(101)			(101)	(102)			(94)			(100)	(101)				(100)	(100)	
Chewaka	Chewaka	12	51	46	49			31	20			44	11	54		24	10				32	17
		(100)	(100)	(97)	(99)			(80)	(80)			(100)	(97)	(95)		(95)	(91)				(96)	(92)
Bahirdar	Zenzlima-	44	20	25	25			66	9			24	11		23	55	23	9	50	43	61	17*
	Robit	(100)	(100)	(75)	(75)			(100)	(100)			(100)	(75)		(112)	(75)	(71)	(75)	(120)	(75)	(100)	(75)
Ameya			16					12				9										
			(100)					(100)				(100)										
Wonchi			23					19				18										
			(100)					(94)				(100)										
Humbo	Abaya		13									13				33					24	
			(74)									(100)				(100)					(100)	
Alamata				44	57			10	89			58	35			19	53				77	80
				(100)	(75)			(100)	(100)			(100)	(75)			(100)	(75)				(100)	(100)
Amibara				45	49			19	61			46	35			87	79				73	70
				(99)	(102)			(94)	(97)			(92)	(101)			(100)	(94)				(103)	(101)
Gambela				(83)	(100)			(88)	(100)			(88)	(100)			(88)	(100)				(88)	

*0.05% alphacypermethrin was used in Bahirdar in 2015

PMI Insecticide Susceptibility Summaries

WHO tube assay for organophosphates, *An. gambiae* s.l., 2012-2015

District	Site	Fenitrothion 1%				Malathion 5%				Pirimiphos-methyl 1%			
		2012	2013	2014	2015	2012	2013	2014	2015	2012	2013	2014	2015
Gida Ayana	Gutin												
Nejo Town													
Dale Sedi	Aweitu- Gendosa	98 (100)											
Gobu Sayo	Gambella	100 (100)											
Ilu Gelan	Tere												
	Siba Biche	100 (100)											
Oma Nada	Asendabo	99 (105)	97 (100)	100 (100)	100 (100)	66 (115)	81 (100)	73 (100)	83 (100)	100 (105)	100 (100)	100 (100)	98 (100)
Halaba	Halaba Town	100 (100)			100 (104)	48 (100)			96 (100)				100* (103)
Zeway- Dugda	Shenen	99 (100)		100 (106)	100 (98)	90 (100)	90 (100)	93 (98)			100 (100)	100* (103)	100* (100)
Chewaka	Chewaka	100 (100)	100 (102)	100 (100)	100 (99)	58 (100)	71 (100)	94 (93)	96 (92)		100 (100)	100 (100)	100* (83)
Bahirdar	Zenzlima-Robit	100 (100)	100 (100)	100 (75)	100 (75)	26 (100)	33 (75)	89 (75)	43 (100)	100 (100)	100 (100)	100 (75)	100* (75)
Ameya			100 (100)				60 (100)				100 (100)		
Wonchi			100 (98)				88 (100)				100 (98)		
Humbo	Abaya		100 (100)				96 (100)				100 (75)		
Alamata				100 (100)	100 (100)			89 (100)	100 (100)			100 (100)	100* (100)
Amibara				100 (102)	100 (99)			100 (101)	100 (102)			100 (99)	100* (101)
Gambela				100 (88)	100 (100)			96 (88)	88 (100)			100 (100)	100 (100)

*0.25% pirimiphos-methyl was used in these areas

PMI Insecticide Susceptibility Summaries

Summarized 2015 CDC bottle assays recording percent mortality after 30 minutes to 1x-10x permethrin and deltamethrin. Mosquitoes from Dugda and Halaba districts were also separately primed with PBO synergists.

Region	District	Permethrin				Deltamethrin			
		1x	2x	5x	10x	1x	2x	5x	10x
Oromia	Asendabo	14	13	42	66	42	67	72	76
	Abedogora	76	95	96	100	91	100	100	100
	Dugda	0	0	80	100	64	64	78	90
	Dugda +PBO	100	100	100	100	100	100	100	100
	Chewaka	0	10	100	100	50	90	100	100
SNNPR	Halaba	0	92	78	100	22	71	89	89
	Halaba +PBO	22	100	71	100	100	100	100	100
	Kachabira	5	80	85	100	5	80	85	95

PMI Insecticide Susceptibility Summaries

GHANA

Ghana began implementing IRS with the support of PMI in 2008, by spraying five northern region districts (Tolon/Kumbungu, Savelugu/Nanton, West Mamprusi, Gushegu, and Karaga), using pyrethroids. The number of districts was steadily scaled up to 9 by adding four new districts (East Mamprusi, Saboba, Chereponi, and Bunkrurugu-Yunyoo) by the close of 2011. In 2012, organophosphates were introduced in some districts, with the remaining regions completing use of pyrethroids. From 2013-2014, PMI used only organophosphates and scaled down to 4 districts (Savelugu/Nanton, East Mamprusi, West Mamprusi, and Bunkpurugu/Yunyoo). Kumbungu district was added in 2015, with all districts continuing to implement IRS solely using organophosphates.

COMMENTS ON DATA:

An. gambiae s.l. mosquitoes were tested. In 2011, WHO susceptibility tests were conducted in 3 of the 9 IRS districts, with the data from Tolon and Savelugu pooled. For 2011 data, 3 test replicates, for a total of 60 mosquitoes, were tested for each insecticide.

PCR results from 2013 and 2014 indicated that both *An. gambiae* s.s. (S form) and *An. coluzzii* (M form) were present, and that their proportions varied over time. A small percentage of *An. gambiae* s.l. in Kulaa were identified as *An. arabiensis* (this was the only site where this species was found). Samples were assayed for *kdr-w* and *ace-1* target site resistance. The majority of *An. gambiae* s.s. (75-95%) were homozygous resistant for *kdr-w*. *Kdr-w* was also present in *An. coluzzii*, but at a lower frequency (35-50% RR, 20-50% RS, 0-20% SS). *Ace-1* is present in both *An. gambiae* and *An. coluzzii* at low frequency. Field-collected mosquitoes also had elevated oxidase and acetylcholinesterase enzyme activity, as compared to the Kisumu reference strain.

In 2015 IRS sites, all specimens collected were PCR-identified as *An. gambiae* s.s. with 62% breaking out as *An. coluzzii* (M) and 38% as *An. gambiae* Giles (S). No hybrid samples were reported. Additionally, the proportion of the population with SS *kdr* alleles continues to increase from 2014. Higher *Ace-1* heterozygote resistant alleles were reported in TD (50%) and BYD (25%). When primed with the synergist PBO, resistant populations from Tarikpaa showed increased survival. The mortality rate increased from about 52% to about 84% ($p=0.0077$) in mosquitoes exposed to PBO before testing them against alpha-cypermethrin, and from 69% to about 97% for deltamethrin ($p=0.0298$). In CDC bottle assays, *An. gambiae* s.l. mosquitoes from Gbullung and Kumbungu were resistant to 1x and 2x diagnostic doses of alpha-cypermethrin, but were susceptible to the 5x and 10x doses. However, *An. gambiae* s.l. from Tarikpaa was highly resistant to 1x, 2x and 5x doses but only susceptible to the 10x dose.

PMI Insecticide Susceptibility Summaries

WHO tube assays for pyrethroids and DDT, on *An. gambiae* s.l., 2013-2015. District abbreviations: T/K (Tolon/Kumbungu), S/N (Savelugu/Nanton), B/Y (Bunkpurugu/Yunyoo), EM (East Mamprusi).

District	Site	Alphacypermethrin 0.05%			Deltamethrin 0.05%		Permethrin 0.75%	Etofenprox 0.5%	DDT 4%		
		2013	2014	2015	2013	2015	2014	2014	2013	2014	2015
T/K	Gbullung	34 (100)	91 (100)	55 (100)	24 (100)	46 (100)		97 (75)	21 (100)	11 (100)	50 (100)
T/K	Woribugu	53 (100)	57 (100)	66 (100)						15 (100)	42 (100)
T/K	Kumbungu			67 (100)		75 (100)					26 (100)
T/K	Dimabi			84 (100)		63.8 (80)					
S/N	Nanton	54 (100)	52 (100)	50 (100)	69(100)	77 (100)			19 (100)		56.3 (80)
S/N	Tarikpaa	24 (100)	92 (100)	55 (100)	75(100)	35 (100)	56 (100)	33 (100)	16 (100)	18 (100)	20 (100)
B/Y	Yunyoo		98 (100)								
B/Y	Bunbuna	78 (100)	97 (75)		62 (100)						
B/Y	Sambiruk	90 (100)			60 (100)						
Tamale	Tugu	98 (100)	92 (100)						23 (100)	23 (100)	
Tamale	Yong				36 (100)						
Tamale	Kulaa		97 (100)	75.8 (100)			36 (100)			9 (100)	
EM	Nalerigu			89 (100)							

PMI Insecticide Susceptibility Summaries

WHO tube assays for carbamates and organophosphates, on *An. gambiae* s.l., 2013-2015. District abbreviations: T/K (Tolon/Kumbungu), S/N (Savelugu/Nanton), B/Y (Bunkpurugu/Yunyoo), EM (East Mamprusi).

District	Site	Propoxur 0.1%		Bendiocarb 0.1%			Fenitrothion 1%		Malathion 5%	Pirimiphos-methyl 0.25%		
		2013	2015	2013	2014	2015	2013	2015	2013	2013	2014	2015
T/K	Gbullung	91 (100)		77 (100)	96 (100)	87 (100)	98 (100)		100 (100)	100 (100)	99 (100)	99 (200)
T/K	Woribugu			74 (100)		93 (100)	96 (80)		100 (100)	100 (100)	100 (100)	95.5 (200)
T/K	Kumbungu		100 (100)			100 (100)						99.5 (200)
T/K	Dimabi					97 (100)						98 (100)
S/N	Nanton	96 (100)		99 (100)	96 (100)	69.4 (100)	100 (100)			100 (100)	99 (100)	100 (100)
S/N	Tarikpaa	81 (100)	99 (100)	90 (100)	94 (100)	100 (100)	99 (100)	100 (100)		100 (100)	100 (100)	100 (100)
B/Y	Yunyoo						100 (100)			100 (100)	98 (100)	98 (100)
B/Y	Bunbuna			91 (100)	99 (100)		100 (100)			100 (100)	99 (100)	100 (100)
B/Y	Sambiruk	95(100)		96 (100)			99 (100)			100 (100)		
Tamale	Tugu	90 (100)			88 (100)		100 (100)			100 (100)	100 (100)	99 (100)
Tamale	Yong									98 (100)		
Tamale	Kulaa				83 (100)	83 (100)					99 (100)	96.4 (193)
EM	Nalerigu											100 (100)

Historical Data: Tolon & Savelugu:

Insecticide	2008	2009	2010	2011
Alphacypermethrin		100	89	97
Deltamethrin	95	95	87	85
Lambdacyhalothrin	99	89	70	77
Cyfluthrin	98		73	
Permethrin	85.5			
Dieldrin		26		
DDT	63	29		
Bendiocarb		89	97	97
Propoxur	90	99	98	
Fenitrothion		97	95	100
Malathion	100	96	98	95

PMI Insecticide Susceptibility Summaries

CONCLUSIONS:

- Resistance to pyrethroids and DDT is high and widespread. There is possible susceptibility to alphacypermethrin in Tamale, but only one data point.
- There is emerging carbamate resistance in all regions.
- Susceptibility to organophosphates remains mostly steady. Possible resistance to fenitrothion was reported in Tolon/Kumbungu in 2014. Also, there is some limited evidence of possible resistance to pirimiphos-methyl in Tolon and Tamale/Kulaa; however, neither site has ever received pirimiphos-methyl IRS.

PMI Insecticide Susceptibility Summaries

GUINEA

PMI supports collection of entomological data in four sentinel sites in Guinea: Boke, Labe, Kissidougou, and Kankan. In addition, the NMCP collected data in Faranah, with support from the Global Fund. PMI does not fund any IRS in Guinea, but some IRS is done by private mining companies.

Laboratory work to determine species and resistance mechanisms of *An. gambiae s.l.* collected in sentinel sites indicated that all collected specimens morphologically identified as *An. gambiae s.l.* were confirmed as *An. gambiae s.s.* with high frequencies of *kdr-w* mutations.

Site	Deltamethrin 0.05%		Permethrin 0.75%		Alphacypermethrin 0.1%	Lambdacyhalothrin 0.05%
	2014	2015	2014	2015	2014	2014
Boke	86 (45)	100 (100)	88 (42)	100 (97)		
Kissidougou	100 (42)	90 (20)	18 (40)	70 (20)	58 (40)	61 (43)
Faranah	100 (75)		43 (75)			
Kankan		100 (70)		89 (70)		

Site	DDT 4%		Bendiocarb 0.1%	
	2014	2015	2014	2015
Boke	44 (45)	75 (95)	100 (45)	100 (98)
Kissidougou	28 (44)	35 (20)	87 (40)	95 (20)
Faranah	31 (75)		100 (75)	
Kankan		63 (64)		100 (67)

CONCLUSIONS:

- There was DDT resistance in all tested sites
- There was resistance to permethrin, alphacypermethrin, and lambdacyhalothrin in all sites tested, but resistance to deltamethrin was only detected in Boke (2014) with possible resistance also in Kissidougou (2015).
- Resistance to bendiocarb was noted in Kissidougou for two straight years, but not in the other sites tested.
- High frequency of *kdr-w* mutations reported across sentinel sites.

PMI Insecticide Susceptibility Summaries

2015: Frequency data available for *kdr-w* and *ace-1* tested at 6 sites for *An. gambiae* s.l. and *An. coluzzii*.

Site	Species	n	kdr-west				Ace1			
			RR	RS	SS	frequency	RR	RS	SS	frequency
Boke	<i>An. coluzzii</i>	19	9	5	5	0.61	0	2	17	0.05
	<i>An. gambiae</i> s.s.	56	43	9	4	0.85	0	5	51	0.04
Faranah	<i>An. coluzzii</i>	38	24	7	7	0.72	0	2	36	0.03
	<i>An. gambiae</i> s.s.	272	203	40	29	0.82	0	21	251	0.04
Kissidougou	<i>An. coluzzii</i>	24	24	0	0	1	0	3	21	0.06
	<i>An. gambiae</i> s.s.	280	264	16	0	0.97	0	27	253	0.05
Labe	<i>An. coluzzii</i>	0	0	0	0	N/A	0	0	0	N/A
	<i>An. gambiae</i> s.s.	10	4	4	2	0.6	0	0	10	0
Maferinyah	<i>An. coluzzii</i>	26	25	1	0	0.98	N/A	N/A	N/A	N/A
	<i>An. gambiae</i> s.s.	1	1	0	0	0	N/A	N/A	N/A	N/A
Kankan	<i>An. coluzzii</i>	121	107	10	4	0.93	N/A	N/A	N/A	N/A
	<i>An. gambiae/coluzzii</i>	6	6	0	0	1	N/A	N/A	N/A	N/A
	<i>An. gambiae</i> s.s.	93	80	6	7	0.89	N/A	N/A	N/A	N/A

PMI Insecticide Susceptibility Summaries

KENYA

The Kenya Division of Malaria Control historically supported focal IRS in 16 epidemic-prone highland districts. In 2008 and 2009, PMI provided additional support for the highland districts, Nandi North and Nandi South, and support to spray the endemic district, Rachuonyo, along the shores of Lake Victoria. In 2010-2011, PMI support for IRS was targeted at three endemic districts: Rachuonyo, Nyando, and Migori. From 2008-2012, PMI-supported IRS was conducted using pyrethroids. IRS was suspended in 2013. Entomological monitoring was supported from 2014-2015.

COMMENTS ON DATA:

Susceptibility data was collected in collaboration with Kenya Medical Research Institute (KEMRI) and in conjunction with Kenya's Division of Malaria Control (DOMC) and their WHO/Insecticide Resistance project.

WHO tube bioassays were used. Numbers were not reported for 2013-2014. For 2016, PCR testing indicated the *An. gambiae* s.l. were primarily *An. arabiensis*.

CONCLUSIONS:

- For *An. gambiae* s.l., data from 2011 was separated by *An. gambiae* s.s. and *An. arabiensis*. For other years, variations in resistance may be due to differing proportions of *An. arabiensis/gambiae* s.s.
- *An. gambiae* s.l. has developed resistance to pyrethroids in all tested areas. Historical data shows that both species have developed resistance to pyrethroids. However, *An. gambiae* s.s. appears to have higher frequencies of pyrethroid resistance.
- *An. gambiae* s.s. is resistant to DDT, but *An. arabiensis* is not (from 2011 data).
- As of 2014, there was evidence of resistance to bendiocarb emerging from Siaya County; *An. gambiae* s.s. from all other tested counties remain susceptible in recent tests. However, 2009-2011 data shows resistance to bendiocarb for *An. gambiae* s.l. in Bungoma, Busia, and Kakamega.
- *An. gambiae* s.l. is fully susceptible to OPs in areas where it has been tested (Kisumu, Homa Bay, Migori).
- *An. funestus* shows resistance to pyrethroids at all sites tested; this species is fully susceptible to pirimiphos-methyl, but shows emerging resistance to bendiocarb at one site in Migori County.

PMI Insecticide Susceptibility Summaries

Results from 2012-2016 WHO tube assay data for *An. gambiae* s.l. – Pyrethroids and Carbamates

County	Location	Deltamethrin 0.05%				Permethrin 0.75%				Bendiocarb 0.1%			
		2012	2013	2014	2016	2012	2013	2014	2016	2012	2013	2014	2016
Kisumu	Nyando	71 (98)	84	63		41 (99)	96			100 (100)	100		
	Muhoroni	78 (100)				80 (100)							
	Nyakach					89 (99)							
Homa Bay	Marindi	74 (168)				52 (46)							
	Ndhiwa	39 (116)			61 (99)	75 (89)			73 (100)				100 (100)
	Rachuonyo	80 (538)	96	70		85 (122)	92			100			
Migori	Homa Bay		60		72 (97)		71		75 (118)				100 (102)
	Nyatike	73 (187)				64 (97)							
	Rongo	60 (53)		34	73 (93)	71 (49)			69 (94)				100 (83)
	Karungu		70				55			100			
	Awendo			67							100		
Bungoma	Uriri				85 (86)				75 (84)				75 (113)
	Bungoma	67 (100)											
	Bumula		45				56						
Busia	Teso North	66 (147)	92			87 (62)	100			100			
	Teso South	78 (191)				75 (58)							
Siaya	Bondo	50 (416)	80			77 (91)	93			100			
	Rarieda	90 (267)				56 (103)							
	Gem		76	47			66	40			75		
	Siaya			48				46			88		
	Ugunja			39				43					

PMI Insecticide Susceptibility Summaries

Results from 2012-2016 WHO tube assay data for *An. gambiae* s.l. – Organophosphates

County	Location	Malathion 5%			Pirimiphos-methyl 0.25%
		2012	2013	2014	2016
Kisumu	Nyando	100 (100)	100		
	Muhoroni				
	Nyakach				
Homa Bay	Marindi				
	Ndhiwa				100 (100)
	Rachuonyo	98 (60)	100		
Migori	Homa Bay				100 (100)
	Nyatike	100 (35)			
	Rongo				100 (123)
	Karungu		100		
	Awendo			100	
Bungoma	Uriri				100 (16)
	Bungoma				
Busia	Bumula				
	Teso North				
Siaya	Teso South				
	Bondo				
	Rarieda				
	Gem			100	
	Siaya			100	
	Ugunja			100	

PMI Insecticide Susceptibility Summaries

2013-2016 *An. funestus* WHO tube assay results

County	Location	Deltamethrin 0.05%			Permethrin 0.75% 2016	Bendiocarb 0.1% 2016	Pirimiphos- methyl 0.25% 2016
		2013	2014	2016			
Siaya	Bondo	75					
Kisumu	Nyando	59	32				
Busia	Teso	20					
Homa Bay	Rachuonyo		24				
Migori	Awendo			85 (88)	86 (83)	93(185)	
	Rongo					100 (15)	
	Uriri					100 (94)	
						100 (114)	
						100 (69)	
						100 (62)	

PMI Insecticide Susceptibility Summaries

Condensed historical (2009-2011) WHO tube assay data for *An. gambiae* s.l. For each insecticide/site, the most recent data point from 2009-2011 is shown.

*Diagnostic dose used for alphacypermethrin unknown

Species	Location	Permethrin 0.75%	Deltamethrin 0.05%	Alphacypermethrin*	Lambdacyhalothrin 0.05%	DDT 4%	Bendiocarb 0.1%	Malathion 5%
		2009-2011	2009-2011	2009-2011	2009-2011	2009-2011	2009-2011	2009-2011
<i>A. gambiae</i> s.l.	Bungoma	84 (148)	89 (88)			78 (54)		
	Busia	54 (347)	78 (249)			21 (78)		
	Kakamega	85 (225)	87 (342)			78 (188)		
	Kisumu W.	84 (231)	91 (22)					
	Teso	68 (627)	89 (774)			64 (59)		
	Nyando	96 (280)	96 (530)		98 (99)		97	
	Rachuonyo	77 (321)	84 (303)	82 (222)	68 (278)			
	Rarieda	60 (920)	78 (787)	66 (684)	41 (763)			
<i>A. gambiae</i> s.s.	Bungoma	28 (104)	63 (104)			62 (37)	83 (99)	100 (44)
	Busia	16 (25)	48 (21)			33 (15)	79 (19)	100 (15)
<i>A. arabiensis</i>	Busia	87 (23)	100 (18)			98 (42)	93 (15)	100 (18)
	Kakamega	82 (11)	100 (15)			100 (8)	82 (11)	100 (10)
	Nyando	92 (137)	92 (130)				98 (160)	
	Rachuounyo	86 (102)	85 (102)					
	Rarieda	97 (64)	83 (29)			100 (36)	100 (34)	100 (24)
	Budalangi	78 (88)	86 (79)			100 (23)	98 (61)	100 (32)
	Kisian	87 (63)	94 (70)			100 (32)	100 (24)	100 (16)

PMI Insecticide Susceptibility Summaries

LIBERIA

PMI was the major supporter of IRS in Liberia from 2009-2013. In 2009, pyrethroids were sprayed in three districts in Grand Bassa and Margibi counties. In 2010, IRS expanded to 8 districts in Grand Bassa, Margibi, and Montserrado counties. In 2011, IRS expanded to Bong and Nimba, for a total of 14 districts in 5 counties. A combination of pyrethroids and carbamates were used in 2011 and 2012, in two rounds. In 2013, 7 districts were sprayed with organophosphates. IRS was suspended in 2014, but PMI continues to support entomological monitoring.

COMMENTS ON DATA:

WHO bioassays were conducted on *Anopheles gambiae* s.l. mosquitoes reared from field-collected larvae.

Molecular testing of specimens collected in 2015 indicated that approximately 97% of specimens morphologically identified as *An. gambiae* s.l. were confirmed to be *An. gambiae* s.s.

CONCLUSIONS:

- There are high levels of resistance to pyrethroids and DDT in all locations tested.
- For organophosphates, there is potential emerging resistance to fenitrothion, but not pirimiphos-methyl.
- There is full susceptibility to carbamates in Montserrado and Grand Gedeh counties, but probable resistance in Bong County (2013-2015) and Grand Bassa (historical data).

PMI Insecticide Susceptibility Summaries

WHO tube assay results for *An. gambiae* s.l.: DDT and pyrethroids, 2012-2015

County	Site	Deltamethrin 0.05%				Alphacypermethrin 0.05%			DDT 4%		
		2012	2013	2014	2015	2012	2013	2015	2013	2014	2015
Montserrado	Montserrado	47 (153)				53 (100)					
	Monrovia			46 (100)						27 (100)	
Bong	SKT			15 (128)	67 (100)			22 (100)		27 (100)	2 (100)
	Suakoko		15 (128)				23 (100)		27 (100)		
	Fuamah		34 (102)								
	Kpaai	52 (101)									
	Jorkole	59 (68)									
Margibi	Mamba kaba	84 (100)				81 (220)					
	Margibi	29 (160)									
Grand Gedeh	Zwedru			62 (100)	62.5 (100)			44.8(100)		30 (100)	26 (100)
Grand Bassa	Bokay Town	12 (25)		78 (100)	68 (100)			27 (100)		54 (100)	4 (100)
Cape Mount	Nimba Point			36 (100)						16 (100)	
Nimba	Sanniquellie				30 (100)			9 (100)			6 (100)
Marigibi					22 (100)			5 (100)			49 (100)
Gbarpolu					73 (100)			47 (75)			

WHO tube assay results, *An. gambiae* s.l.: carbamates and organophosphates, 2012-2015

County	Site	Bendiocarb 0.1%				Fenitrothion 1%			Pirimiphos-methyl 0.25%		
		2012	2013	2014	2015	2012	2013	2014	2012	2013	2015
Montserrado	Monrovia			99 (100)				95 (100)			
Bong	SKT			95 (100)	97 (100)			100 (102)			100 (100)
	Suakoko		95 (100)				100 (102)			100 (100)	
	Kpaai					94 (143)			100 (81)		
Margibi	Margibi	100 (44)				98 (40)			100 (91)		
Grand Gedeh	Zwedru			98 (100)	100 (100)			100 (100)			100 (100)
Grand Bassa	Bokay Town				94 (100)			100 (100)			
Nimba	Sanniquellie				94 (100)						100 (100)
Marigibi					97 (100)						100 (100)
Gbarpolu					89 (100)						100 (100)

PMI Insecticide Susceptibility Summaries

Historical data: WHO tube assays for *An. gambiae* s.l., condensed, 2009-2011. For each county/insecticide combination, the most recent data between 2009-2011 is shown.

Counties	Deltamethrin 0.05%	Lambdacyhalothrin 0.05%	Bendiocarb 0.1%	DDT 4%	Fenitrothion 1%
Bong	87 (86)	82 (65)	85 (60)		100 (19)
Grand Bassa	98 (72)	90 (40)	95 (41)	98 (58)	98 (41)
Margibi	94 (79)	93 (87)	100 (60)	100 (37)	100 (45)
Montserrado	82 (49)	87 (88)	99 (85)	98 (42)	100 (96)
Nimba	100 (24)	89 (41)	100 (40)		

MADAGASCAR

PMI began implementing the IRS program in Madagascar in 2008 with seven districts and scaled up to 18 districts in 2010. In 2011-2013, 15 districts in the Central Highlands and Southern Madagascar were sprayed. IRS in Madagascar has used a mix of insecticides, starting with pyrethroids in 2008-2009, introducing carbamates in 2010, and introducing organophosphates in 2013. In 2014, 6 districts in the Central Highlands (targeted spraying, pyrethroids and carbamates) and 3 districts in Eastern Madagascar (blanket spraying, organophosphates) were sprayed. Five districts were covered in the 2015 IRS campaign, with organophosphates the sole insecticide used.

COMMENTS ON DATA:

Resistance monitoring in Madagascar is carried out by the National Malaria Control Program (PNLP), via Global Fund financing, the Institute Pasteur Madagascar (IPM), and PMI.

Molecular analysis by Institute Pasteur Madagascar in 2014 indicated that of the total tested – 26.8% were identified as *An. arabiensis* and 73.2% were *An. gambiae* s.s.

WHO tube bioassays were conducted; in some circumstances CDC bottle bioassays were performed. For CDC assays: lambda-cyhalothrin, permethrin, alphacypermethrin, and deltamethrin tests were conducted with 12.5 ug/bottle; bendiocarb tests were conducted with 12.5 ug/bottle; fenitrothion tests with 50 ug/bottle; and DDT tests with 100ug/bottle.

CONCLUSIONS:

- For *An. gambiae* s.l., there are few remaining sites with susceptibility to DDT.
- In 2015, for *An. gambiae* s.l. tested, there is emerging resistance to pyrethroids at some sites, two sites with confirmed resistance and four sites with possible resistance. For *An. gambiae* s.l., there is full susceptibility to carbamates in most sites, with a few reports of suspected resistance, and confirmed resistance in Ambohidratrimo and Marovoay. However, retesting of some of the suspected resistant sites in later years confirmed susceptibility.
- For *An. gambiae* s.l., there are a few reports of suspected resistance to fenitrothion, but full susceptibility to pirimiphos-methyl as of 2015.
- For *An. funestus*: There appears to be emerging resistance to pyrethroids in Tsaratanana, and confirmed resistance to bendiocarb in Miarinarivo. There is full susceptibility in all other tested sites and to other insecticides, but overall there is not much data.

PMI Insecticide Susceptibility Summaries

An. gambiae s.l. WHO tube and CDC bottle bioassay results, pyrethroids. * indicates CDC bottle bioassay; § denotes late year 2015 testing

District	Deltamethrin 0.05%					Lambdacyhalothrin 0.05%					Permethrin 0.75%					Alphacypermethrin 12.5mg/bottle						
	2012	2013	2014	2015	2015 [§]	2012	2013	2014	2015	2015 [§]	2012	2013	2014	2015	2015 [§]	2012	2013	2014	2015	2015 [§]		
AMBANJA	100 (80)																					
AMBILOBE	100 (100)	100 (100)				100 (100)	100 (100)				100 (100)*	100 (100)				100 (100)*						
AMBOASARY	99 (100)	100 (100)	100 (100)			100 (102)	100 (100)	98 (100)				99 (100)*	98 (100)			100 (101)*	100 (100)*	96 (100)*				
AMBATOFINANDRA HANA	100 (100)	100 (100)	100 (100)			96 (100)	99 (100)	97 (100)				97 (100)*	99 (100)				100 (100)*	89 (100)*				
AMBATO BOENI											100 (60)											
AMBOHIDRATRIMO	100 (100)																					
AMBOVOMBE	98.5 (200)*					99 (100)*					99 (100)*		99 (100)*			100 (200)*						
AMBOHIMAHASOA			100 (100)	100 (100)	100 (100)			100 (100)	99 (100)	99 (100)			100 (100)	100 (100)	97 (100)			100 (100)*	100 (100)*	100 (100)*		
AMBOSITRA			99 (100)	100 (100)	100 (100)			100 (100)	98 (100)	96 (100)			99 (100)	99 (100)	99 (100)			100 (100)*	94 (100)*	95 (100)*		
AMPANIHY			98 (100)					99 (100)					98 (100)						95 (100)*			
ANKAZOBE	100 (100)	100 (100)	98 (100)			100 (100)	100 (100)	96 (100)				100 (100)*	80 (100)			100 (100)*	100 (100)*	100 (100)*				
ANTOETRA (in Ambositra district)		100 (100)					99 (100)					100 (100)*					100 (100)*					
ANTSIRABE 2	100 (100)					86 (100)					94 (100)											
BEKILY	100 (200)*		98 (100)	100 (100)	100 (100)	100 (200)*		100 (100)	100 (100)	85 (100)	100 (200)*		99 (100)	100 (100)	80 (100)	100 (200)*		95 (100)*	91 (100)*	100 (100)*		
BETAFO	99 (100)	100 (100)	100 (100)			100 (100)	100 (100)	100 (100)				82 (100)*	100 (100)				100 (100)*	97 (100)*				
BETROKA	100 (100)					100 (100)					100 (100)											
BORIZINY	87 (100)					83 (100)					82 (100)											
BRICKAVILLE	100 (100)	100 (100)		100 (100)	100 (100)	100 (100)	100 (100)		98 (100)	99 (100)	100 (100)*	84 (100)*		98 (100)	100 (100)	100 (100)*	100 (100)*			100 (100)*	100 (100)*	
FANDRIANA				100 (100)	100 (100)				100 (100)	100 (100)				100 (100)	100 (100)					100 (100)*	100 (100)*	
FARAFANGANA					100 (100)					100 (100)					100 (100)						99 (100)*	
FENERIVE EST				99 (100)	99 (100)				100 (100)	99 (100)				95 (100)	99 (100)					91 (100)*	91 (100)*	
FENOARIVO BE	100 (100)					97 (100)					98 (100)											
FIANARANTSOA II				100	100				100	100				100	100						100	100

PMI Insecticide Susceptibility Summaries

		(100)	(100)		(100)	(100)		(100)	(100)		(100)*	(100)*	
FORT DAUPHIN	100	100		100	100		99	94		100	95		
	(100)	(100)		(100)	(100)		(101)*	(100)		(100)*	(100)*		
MAHABO	100			99			98	(100)					
	(100)			(100)									
TOAMASINA II			93	92					96	100		98	97
			(100)	(100)					(100)	(100)		(100)*	(100)*
TSARATANANA	100				97		100				97		
	(100)				(100)		(100)*				(100)*		
VANGAINDRANO				100						100			100
				(100)						(100)			(100)*
VAVATENINA			92	98			100	100	100	82		100	100
			(100)	(100)			(100)	(100)	(100)	(100)		(100)*	(100)*

PMI Insecticide Susceptibility Summaries

An. gambiae s.l. WHO tube bioassay results: DDT, carbamates, and organophosphates; [§]denotes late year 2015 testing;

District	DDT 4%					Bendiocarb 0.1%					Propoxur 0.1%	Fenitrothion 1%		Pirimiphos-methyl 0.25%			
	2012	2013	2014	2015	2015 [§]	2012	2013	2014	2015	2015 [§]	2012	2012	2013	2014	2015	2015 [§]	
AMBANJA	100 (80)																
AMBILOBE	100 (100)	100 (100)				100 (100)	100 (100)					100 (100)	100 (100)				
AMBOASARY	98 (100)	98 (100)	97 (100)			100 (103)	100 (100)	100 (100)				100 (100)	100 (100)				
AMBATOFINANDRAHANA	97 (100)	87 (100)	97 (100)			100 (100)	98 (100)	100 (100)				97 (100)	100 (100)	100 (100)			
AMBOHIDRATRIMO						86 (100)											
AMBOVOMBE	100 (100)*					100 (200)*						99 (200)*					
AMBOHIMAHASOA			85 (100)	98 (100)	30 (100)			100 (100)	100 (100)	100 (100)							
AMBOSITRA			98 (100)	27 (100)	56 (100)			98 (100)	99 (100)	100 (100)							
AMPANIHY			93 (100)					100 (100)									
ANDILAMENA																	
ANJOZOROBE																	
ANKAZOBE	48 (100)	72 (100)	77 (100)			100 (100)	100 (100)	100 (100)				100 (100)	100 (100)	100 (100)			
ANTOETRA (in Ambositra district)		95 (100)						99 (100)					100 (100)				
ANTSIRABE 2											100 (100)	100 (100)					
ATSIMONDRANO																	
BEKILY	99 (200)*		100 (100)	100 (100)	100 (100)	100 (200)*		98 (100)	98 (100)	100 (100)		94 (200)*		100 (100)	100 (100)	100 (100)	
BETAFO	68 (104)	36 (100)	86 (100)			100 (100)	100 (100)	100 (100)				100 (100)	100 (100)	100 (100)			
BETIOKY SUD																	
BETROKA											100 (100)						
BORIZINY	93 (100)					94 (100)						99 (100)					
BRICKAVILLE		97 (100)		96 (100)	100 (100)	100 (101)	100 (100)		100 (100)	100 (100)		100 (101)	100 (100)			100 (100)	100 (100)
FANDRIANA				93 (100)	96 (100)												
FARAFANGANA					100 (100)												
FENERIVE EST				100 (100)	99 (100)				100 (100)	100 (100)							
FENOARIVO BE											100 (100)						
FIANAR II																	

PMI Insecticide Susceptibility Summaries

FIANARANTSOA II			29 (100)	45 (100)			100 (100)	100 (100)				99 (100)	100 (100)
FORT DAUPHIN	92 (100)	90 (100)			100 (100)	100 (100)				100 (100)	100 (100)		
MAHABO								100 (100)					
TOAMASINA II			99 (100)	100 (100)			100 (100)	100 (100)				100 (100)	100 (100)
TSARATANANA					100 (100)					95 (100)			
VANGAINDRANO				100 (100)				100 (100)					100 (100)
VAVATENINA			100 (100)	100 (100)			100 (100)	100 (100)				100 (100)	100 (100)

An. funestus WHO tube bioassay results, 2009-2012. 2006-2008 indicates the most recent data point from that time period.

Site	Deltamethrin 0.05%		Permethrin 0.75%	Lambdacyhalothrin 0.05%		DDT 4%			Bendiocarb 0.1%		Fenitrothion 1%		Propoxur 0.1%
	2009	2012	2012	2010	2012	2006-08	2010	2012	2006-08	2012	2010	2012	2012
AMBATO BOENI				100 (80)		100 (80)		100 (60)		100 (60)	100 (80)		
AMBILOBE				100 (80)									
ANJOZOROBÉ						98 (111)							
ANKAZOBÉ									100 (48)				
MIARINARIVO		99 (100)	100 (100)	100 (75)	100 (100)		100 (75)	100 (100)		44 (100)		100 (100)	100 (100)
TSARATANANA				97 (173)									
TSI/DIDY	100 (142)												

PMI Insecticide Susceptibility Summaries

MALAWI

From 2007 to 2009, IRS was conducted by PMI in Nkhatakota District with pyrethroids. In 2010 and 2011, IRS was scaled up to an additional six districts (Karonga, Nkhata Bay, Salima, Mangochi, Chikwawa, and Nsanje). IRS in Nkhatakota and Salima was funded by PMI and used an organophosphate, while IRS in the remaining districts was funded by the Malawi government and used pyrethroids. In 2011 PMI only sprayed Nkhatakota, again with organophosphate. PMI-supported IRS was suspended in 2012, but the government has continued some spraying with pyrethroids. PMI backing of entomological monitoring has continued through 2015.

COMMENTS ON DATA:

Susceptibility data was collected in collaboration with the Malaria Alert Center (MAC) and NMCP. *An. funestus* were used for testing in WHO tube assays. For *An. gambiae* s.l., adults were reared from field-collected larvae. For 2014 and 2015, sample sizes were not reported. Some earlier *An. funestus* data has been pulled from Hunt et al. 2010, *Parasit Vectors*.

2014 molecular results: *An. gambiae* s.l. are primarily *An. arabiensis*, with a smaller percentage of *An. gambiae* s.s. For *An. funestus* pyrethroid resistance mechanisms, "pre-exposure of *An. funestus* to piperonyl butoxide (PBO) followed by exposure to pyrethroids did not result in complete recovery as shown by mortality rates of 80% and 84% to permethrin and deltamethrin respectively observed at Ntuwana village in Chikwawa district and 63% mortality at Chimkwende village in Nkhatakota district." (mortality without PBO = 17% and 15%, and 3% and 2%, respectively)

CONCLUSIONS:

- *An. funestus* in Malawi shows strong resistance to pyrethroids, carbamates, and DDT. Metabolic resistance by elevated MFOs has been implicated as a mechanism.
- *An. funestus* shows full susceptibility to organophosphates.
- Though there is less data for *An. gambiae* s.l., it shows resistance to pyrethroids and carbamates (although only one district was tested with carbamates). There have been no recent tests for organophosphates, but 2011 data from Chikwawa shows susceptibility to malathion.

PMI Insecticide Susceptibility Summaries

An. funestus, pyrethroid and DDT WHO tube assays. 2010-2012 data represents the most recent data point within that time period. In 2013, limited mosquito numbers prevented extensive insecticide resistance assays. 2015 data represent join PMI and NMCP results: WHO assays were performed using specimens from 1-4 sites, range for % mortality shown.

District	Deltamethrin 0.05%			Permethrin 0.75%			Lambdacyhalothrin 0.05%	DDT 4%		
	2010-12	2014	2015	2009-12	2014	2015	2010-12	2010-12	2014	2015
Mangochi	74 (116)		37%	79 (191)	14	44%	70 (98)			
Chikwawa	39 (199)	15	12-26%	78 (201)	18	0-29%	66 (276)	93 (278)	100	75%
Salima	58.5 (254)	21	8-41%	69 (175)	20	25-32%	32 (190)	90 (100)		
Nkhotakota	46 (414)	2-3	0-8%	73 (301)	3-10	25%	36 (294)	99 (102)		
Nkhata Bay	21 (100)	11	11-14%	80 (200)	50	14%	30 (200)	97 (184)		
Machinga	44 (336)		7%	70 (209)		0%				
Dedza	54 (461)			81 (124)			36 (100)			
Likoma	41 (174)			40 (146)				100 (155)		
Phalombe		11			57					

An. funestus, carbamate and organophosphate WHO tube assays. 2010-2012 data represents the most recent data point within that time period. 2015 data represent join PMI and NMCP results: WHO assays were performed using specimens from 1-4 sites, range for % mortality shown. *Concentration not reported

District	Bendiocarb 0.1%			Propoxur 0.1%			Malathion 5%			Pirimiphos-methyl*	
	2010-12	2014	2015	2010-2012	2014	2015	2010-12	2014	2015	2010-12	2014
Mangochi	99 (100)						100 (100)				
Chikwawa	64 (256)	5	19%	83 (124)	0	7%	100 (100)	100	100%		100
Salima	59 (101)						100 (100)				
Nkhotakota	67 (75)	6					100 (25)	100		100 (78)	
Karonga	80 (101)										
Nkhata Bay	83 (203)	21		84.5 (200)			100 (196)			100 (141)	
Dedza	41 (100)						100 (50)				
Likoma	52 (141)			7 (54)			100 (126)			99 (99)	

PMI Insecticide Susceptibility Summaries

An. gambiae s.l., WHO tube assays. 2010-2011/12 data represents the most recent data point within that time period.

District	Deltamethrin 0.05%			Permethrin 0.75%			Lambdacyhalothrin 0.05%	Bendiocarb 0.1%		Malathion 5%
	2010-11	2014	2015	2009-11	2014	2015	2010-11	2010-12	2014	2010-11
Chikwawa	100 (110)		69%	82 (81)	56	44%	96 (81)	100 (100)		100 (23)
Salima	65 (21)	89		99 (125)	77			100 (100)		
Nkhotakota				89 (27)	48					
Karonga	100 (590)	58	95-97%	98 (374)	40-82		100 (86)		56	
Nkhata Bay				90.5 (95)	78			100 (50)		
Machinga	87.5 (8)		80%							
Nsanje				88 (113)						
Blantyre							100 (25)			
Phalombe			65-78%		71	46-47%				
Chitipa			100%							
Kasunga			75%			53%				
Mchinji			63%							
Dedza			57%							
Mangochi			84%		71	58%				
Zomba			89%							
Mwanza			97%							

PMI Insecticide Susceptibility Summaries

MALI

PMI is the sole supporter of IRS in Mali. From 2008 to 2010, IRS was conducted with a pyrethroid in Bla and Koulikoro. In 2011-2013, the district of Baroueli was added, and carbamates were used in all three districts. In 2014, the same three districts were sprayed, this time with an organophosphate. IRS was limited to 2 districts in 2015, Baroueli and Koulikoro – repeating with organophosphates.

COMMENTS ON DATA:

Susceptibility data was collected in collaboration with University of Bamako. Results presented are for *An. gambiae* s.l., from WHO tube assays performed on adults raised from field-collected larvae or F1 mosquitoes.

The *kdr* target site resistance mutation for pyrethroids and DDT occurs at high frequency in both the M and S forms of *An. gambiae* (70-95% allele frequency). The *ace-1* resistance mutation for carbamates and OPs occurs at low frequency (0-4%). *An. gambiae* s.l. shows significantly elevated mixed-function oxidases and glutathione S-transferases, indicating metabolic resistance.

Intensity data shows that phenotypic resistance is maintained when challenged with increasing concentrations of pyrethroids, except at four sites where moderate levels of susceptibility were reported when the 10x diagnostic dose was used. Additionally, priming with synergists before testing showed limited restoration of susceptibility.

WHO tube bioassay results (2009-2015) for *An. gambiae* s.l., pyrethroids and DDT. 2009-2012 indicates the most recent data point for that site.

Site	Deltamethrin 0.05%				Permethrin 0.75%			Lambdacyhalothrin 0.05%		DDT 4%			
	2009-12	2013	2014	2015	2009-10	2014	2015	2009-12	2013	2009-12	2013	2014	2015
Koulikoro	50 (300)	98 (104)	15 (104)	49 (100)		6 (102)	14 (100)	13 (98)	13 (100)	11 (95)	10 (99)	4 (104)	37 (100)
Bla	68.5 (400)	38 (103)	14 (98)	64 (100)		47 (100)	83 (100)	58 (102)	77 (103)	48 (99)	52 (104)	6 (101)	41 (100)
Baraoueli	61 (300)	50 (101)	31 (100)	66 (100)	79 (300)	25 (102)	21 (100)	33 (100)	45 (103)	13 (93)	35 (104)	16 (90)	15 (100)
Bamako	80 (100)		6 (102)	79 (100)	75 (100)	1 (103)	63 (100)	7		18		7 (100)	24 (100)
Kati	97 (200)		18 (104)	38 (100)	68 (200)	25 (102)	7 (100)	12		17		1 (100)	7 (100)
Gao	94 (100)				69 (100)			74 (100)		95 (100)			
Niono	91 (200)		42 (97)	58 (100)	97 (200)	11 (103)	49 (100)	33		44		5 (103)	7 (100)
Badiangara	79		30 (100)	45 (100)	79.5 (200)	32 (100)	22 (100)	66.5 (200)		76		14 (100)	28 (100)
Bougouni	91		77 (100)	79 (100)	98.5 (200)	60 (100)	85 (100)	87.5 (200)		28		1 (104)	68 (100)
Kita	88 (200)		64 (99)	98 (100)	98 (200)	19 (100)	65 (100)	74		75		1 (100)	
Djenné	16		40 (100)	41 (100)	100 (100)	21 (101)	19 (100)	94 (100)		42		19 (104)	31 (100)
Tombouctou	97 (100)				98 (100)			100 (100)		52 (100)			
Bankass	32		37 (100)	90 (100)		54 (100)	87 (100)			47		25 (100)	55 (100)
Kadiolo			43 (100)	63 (100)		13 (100)	54 (100)	37		12		6 (100)	40 (100)
Yanfoila			42 (100)			72 (104)		50		23		13 (100)	
Selingue				56 (100)			57 (100)						30 (100)

PMI Insecticide Susceptibility Summaries

WHO tube bioassay results (2009-2015) for *An. gambiae* s.l., carbamates and organophosphates. 2009-2012 or 2009-2010 indicates the most recent data point for that site.

Site	Bendiocarb 0.1%				Fenitrothion 1%			Pirimiphos-methyl 0.25%	
	2009-12	2013	2014	2015	2009-10	2012	2013	2014	2015
Koulikoro	98 (96)	100 (102)	100 (104)	100 (100)		99 (99)	100 (99)	100 (104)	100 (100)
Bla	88 (102)	98 (103)	94 (101)	100 (100)		98 (119)	100 (102)	100 (102)	100 (100)
Baraoueli	98 (90)	98 (101)	97 (100)	99 (100)		97 (99)	100 (102)	100 (101)	100 (100)
Bamako	100		96 (102)	98 (100)	100 (100)	99		100 (103)	100 (100)
Kati	96 (50)		100 (104)	100 (100)	100 (200)	100		100 (100)	100 (100)
Gao	100 (100)				100 (100)				
Niono	100		100 (100)	100 (100)	100 (200)	93		99 (101)	100 (100)
Badiangara	100		100 (100)	100 (100)	100 (200)	100		100 (100)	100 (100)
Bougouni	85		84 (103)	100 (100)	99 (200)	97		100 (104)	100 (100)
Kita	66		95 (99)		98.5 (200)	99		99 (100)	
Djenné	100		99 (104)	100 (100)	98 (100)	100		100 (100)	100 (100)
Tombouctou	100 (100)				100 (100)				
Bankass	100		100 (100)	100 (100)		100		100 (103)	100 (100)
Kadiolo	78		92 (100)	94 (100)		84		100 (100)	100 (100)
Yanfoila	100		99 (100)			100		100 (100)	
Selingue				100 (100)					100 (100)

2015 PBO synergist results

District	Permethrin				Deltamethrin			
	Insecticide only		+ PBO		Insecticide only		+ PBO	
	%	#	%	#	%	#	%	#
Koulikoro	19 R	100	27 R	93	70 R	101	93* PR	102
Kati	30 R	104	47* R	100	71 R	104	85* R	100
Bamako CIV	47 R	100	46 R	100	81 R	100	89 R	104
Bla	4 R	101	54* R	101	34 R	102	78* R	100
Baroueli	9 R	104	61* R	102	78 R	103	71 R	80
Niono	10 R	100	24* R	100	58 R	102	84* R	100
Selingue	32 R	95	85* R	26	14 R	51	30* R	47
Bougouni	21 R	102	67* R	104	52 R	102	80* R	102
Kadiolo	9 R	100	25* R	100	31 R	100	73* R	100
Djenne	0 R	104	20* R	104	61 R	100	68 R	100
Bandigara	29 R	104	68* R	104	79 R	104	92* PR	103
Bankass	47* R	104	30 R	100	82* R	104	64 R	104

PMI Insecticide Susceptibility Summaries

CDC bottle bioassays show high pyrethroid resistance intensity:

Site	Permethrin									Deltamethrin								
	2014	2015								2014	2015							
	10x	1X		2X		5X		10X		10x	1X		2X		5X		10X	
	%	%	#	%	#	%	#	%	#	%	%	#	%	#	%	#	%	#
Koulikoro	22	19	100	9	100	14	100	66 R	100	57	70	101	51	101	80	103	94 PR	102
Kati		30	104	29	101	73	26	n/a	n/a		71	104	74	104	58	50	n/a	n/a
Bamako CIV		47	10	19	100	84	100	82 R	104		81	100	40	104	28	100	86 R	104
Bla	73	4	101	20	101	38	102	45 R	102	91	34	102	73	102	71	101	84 R	101
Baroueli	86	9	104	20	103	38	103	60 R	103	100	78	103	80	102	75	102	91 PR	103
Niono		10	100	2	101	16	101	80 R	101		58	102	44	102	53	101	76 R	100
Selingue		32	95	40	100	42	101	63 R	51		14	51	46	52	47	51	64 R	47
Bougouni		21	102	28	101	19	75	55 R	51		52	102	10	50	48	50	76 R	50
Kadiolo		9	100	14	100	32	100	69 R	100		31	100	44	100	71	100	84 R	100
Djenne		0	104	1	104	51	100	65 R	101		61	100	75	100	72	100	95 PR	100
Bandigara		29	104	2	104	76	104	92 PR	104		79	104	63	103	27	104	88 R	104
Bankass		47	104	13	104	92	104	84 R	104		82	104	73	104	22	104	84 R	104

CONCLUSIONS:

- In *An. gambiae* s.l., there is probable or confirmed resistance to pyrethroids and DDT in all districts, often with high resistance frequency and intensity.
- Pyrethroid and DDT resistance is due to a combination of high *kdr* frequency and metabolic resistance.
- Phenotypic resistance to pyrethroids is only moderately affected by increasing the diagnostic concentration of insecticides and the use of synergists; full susceptibility was not restored.
- *An. gambiae* s.l. is susceptible to carbamates and organophosphates in IRS districts. However, in some non-IRS districts, confirmed resistance to carbamates and probable resistance to fenitrothion has previously been reported. Testing in 2015 indicated full susceptibility to pirimiphos-methyl in all sites and bendiocarb in all but one site where probable resistance was noted.

MOZAMBIQUE

In 2005, the NMCP resumed IRS in Zambezia in three districts, using DDT. IRS was expanded to cover five districts in 2006, and this effort was strengthened in 2007 by PMI. IRS was focused on densely populated areas using DDT or lambda-cyhalothrin. In 2009, IRS transitioned to only pyrethroids. In 2011, 8 districts in Zambezia Province were sprayed – Quelimane, Nioadala, Namacurra, Mocuba, Morrumbala, Milange, Maganja da Costa, and Mopeia. In 2014, 5 districts were sprayed with pyrethroids: Mocuba, Milange, Morrumbala, Quelimane, and Mopeia. In 2015, Milange, Molumbo, and Quelimane were sprayed with pyrethroids, while Morrumbala, Mocuba, and Derre were sprayed with pirimiphos-methyl.

COMMENTS ON DATA:

2013-2014 collections: *An. gambiae* s.l. and *An. funestus* reared from field-collected larvae were tested. Mosquitoes were tested from 3 IRS sites (Mocuba, Morrumbala, and Milange).

2015-2016 collections: *An. gambiae* s.l. larvae collected from sentinel sites, including three IRS sites (Mocuba, Morrumbala, and Milange), were used for susceptibility testing; *An. funestus* s.l. has not been tested since 2014, despite monitoring data that *An. funestus* is likely the predominant vector in some locations.

CONCLUSIONS:

- General insecticide resistance trends indicate susceptibility for *An. gambiae* s.l. to pyrethroids in most areas. However, there is confirmed resistance to pyrethroids in Mocuba and Morrumbala. There is probable resistance to DDT in Nampula, Manica, and Manpula provinces. *An. gambiae* s.l. is susceptible to carbamate, and organophosphate in all tested areas.
- *An. funestus* is beginning to show low to moderate pyrethroid resistance in several districts in Zambezia, Niassa, Tete, and Maputo provinces.
- Early data shows probable *An. funestus* carbamate resistance in Mocuba and Milange. *An. funestus* also shows probable resistance to fenitrothion in Mocuba. NMCP testing with pirimiphos-methyl reported *An. funestus* s.l. fully susceptible at all test sites.

PMI Insecticide Susceptibility Summaries

WHO tube assays for Zambezia Province, *An. gambiae* s.l., 2013-2016.

Sites	Deltamethrin 0.05%				Lambdacyhalothrin 0.05%				DDT 4%				Bendiocarb 0.1%				Fenitrothion 1%				P methyl*
	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2016
Mocuba		100 (100)	74 (300)	51 (100)		100 (100)	92 (300)	40 (100)		100 (100)	100 (100)	98 (100)		100 (100)	99 (100)	98 (100)		100 (100)	100 (100)	98 (100)	100 (100)
Morrumbala	97 (100)		91 (300)	34 (100)	95 (100)		69 (100)	33 (100)	98 (100)		100 (100)	100 (100)	100 (100)		100 (100)	100 (100)	100 (100)			100 (100)	100 (100)
Nicoadala	100 (100)												100 (100)								
Milange			100 (100)	71 (100)				45 (100)			100 (100)					100 (100)				100 (100)	100 (100)

*P-methyl denotes pirimiphos-methyl (0.25%) tested

WHO tube assays for Zambezia Province, *An. funestus* 2007-2014. 2007-2012 indicates the most recent data point from that time period. Some data from Abilio 2011, Malar J.

District	Deltamethrin 0.05%			Lambdacyhalothrin 0.05%			Bendiocarb 0.1%			DDT 4%			Fenitrothion 1%	
	2007-2012	2013	2014	2007-2010	2013	2014	2007-2010	2013	2014	2007-2010	2013	2014	2013	2014
Maganja da Costa	100 (50) [#]			100 (50)			100 (50)			100 (75)				
Mocuba	100 (20)	94 (100)		76 (234)	93 (100)		93.5 (229)	98 (100)		100 (85)	100 (100)		94 (100)	
Morrumbala	100 (60) [#]		92 (100)			100 (100)			99 (100)	100 (92)		100 (100)		100 (100)
Namacurra										100 (20)				
Nicoadala	100 (25) [#]				100 (100)					100 (25)	100 (100)		100 (100)	
Milange	100 (193) [*]	92 (100)	100 (50)	83 (159)			84 (207)			100 (193)				
Quelimane	100 (28)			100 (50)										

[#] Test conducted with 0.025% Deltamethrin

^{*} Test conducted with Permethrin 0.75%

PMI Insecticide Susceptibility Summaries

Additional 2015 data on *An. gambiae* s.l. susceptibility collected by the NMCP with PMI support. *Concentration not reported

Province	District	Lambdacyhalothrin 0.05%	Deltamethrin 0.05%	Bendiocarb 0.01%	DDT 4%	Pirimiphos- methyl*	Fenitrothion 1%
Cabo Delgado	Metuge	84 (100)	99 (100)	100 (100)	100 (100)		
	Montepuez	88 (100)	96 (100)	100 (100)	100 (100)		
Nampula	C. Nampula	100 (100)	99 (100)	100 (100)	100 (100)	100 (100)	
	Meconta	100 (100)	100 (100)	100 (100)	100 (100)		
Manica	Gondola	96 (80)	96 (80)	95 (80)	94 (160)		
	Chimoio	92 (105)	86 (105)	98 (105)	88 (105)	100 (120)	
Tete	C. Tete	74 (100)	86 (100)	98.5 (200)	99 (100)		
Sofala	Beira	96.5 (200)	99 (100)	100 (100)	98 (100)		100 (100)
	Dondo	98 (100)	96.5 (100)	100 (100)	99 (100)		100 (100)
Inhambane	C. Inhambane	100 (100)	100 (100)	100 (100)	100 (100)		
Gaza	Chokwe		100 (100)		100 (100)	100 (50)	
	Xai-Xai	100 (100)	100 (100)	100 (100)	100 (50)	98 (100)	
Maputo	Boane	100 (100)	93 (100)	65 (100)	100 (100)	100 (100)	
	Magude	89 (123)	93 (100)	81 (100)	97 (100)	100 (100)	
Cidade de Maputo	Moamba	100 (100)	100 (100)	100 (114)	99 (100)	100 (100)	
	DU. Ka Maxaquene	77 (120)	90 (100)	99 (125)	98 (125)	98 (125)	

Additional 2015 data on *An. funestus* susceptibility collected by NMCP with PMI support. *Concentration not reported

Province	District	Lambdacyhalothrin 0.05%	Deltamethrin 0.05%	Bendiocarb 0.01%	DDT 4%	Pirimiphos- methyl*
Niassa	C. Lichinga		58 (100)		100 (100)	
Tete	Moatize		85 (100)	100 (100)	100 (100)	
Maputo	Magude	88 (100)	94 (100)		99 (108)	100 (100)

PMI Insecticide Susceptibility Summaries

NIGERIA

The first round of PMI-supported IRS occurred in 2012 in Nasarawa Eggon and Doma LGAs in Nasarawa state, with pyrethroids. Pyrethroids were used again in 2013, and IRS was suspended in 2014.

COMMENTS ON DATA:

Susceptibility data was collected in collaboration with: University of Jos; Abubakar Tafawa Balewa University Bauchi; Rivers State University of Science and Technology; Nasarawa State University Keffi; Institute for Advanced Medical Research and Training, College of Medicine, University of Ibadan; National Arbovirus and Vector Research Center Enugu; and Usmanu Danfodiyo University Sokoto.

Molecular results: The resistant *kdr* allele was very high in Epe (85% and 92% of deltamethrin and DDT survivors respectively). Cross-resistance between deltamethrin and DDT was also observed in Nasarawa Eggon where the *kdr* allele was 65% and 76% in DDT and deltamethrin survivors, respectively. The diagnostic *kdr* resistant band was present in < 5% of the dead mosquito from both sites. In 2015, molecular analysis determined 79% of specimens collected across sites were *An. gambiae* s.s and 21% were *An. arabiensis*.

PBO synergist results: Results from 2015, show partial restoration of susceptibility to deltamethrin with pre-exposure to PBO in Lagos.

Intensity assays: 2015 intensity results indicated that susceptibility to deltamethrin was restored to a range of 93-100% across sites at the 10x diagnostic dose.

CONCLUSIONS:

- High level pyrethroid and DDT resistance is widespread
- Molecular & synergist assays indicate that pyrethroid and DDT resistance is mediated by *kdr* target site resistance, and in limited cases, susceptibility can be partially restored with pre-exposure to PBO.
- Other than Lagos and Doma, all populations show resistance to pirimiphos-methyl, but additional testing is required to confirm. IRS with pirimiphos-methyl has not been conducted in Nigeria.
- Fenitrothion was shown to cause 100% mortality in one test site, but has not been tested since 2013.
- Populations remain mostly susceptible to bendiocarb, but resistance to propoxur is likely emerging.

PMI Insecticide Susceptibility Summaries

WHO tube assays for *An. gambiae* s.l., 2013-2015: Pyrethroids and DDT

Region	Permethrin 0.75%		Deltamethrin 0.05%			Alphacypermethrin 0.5%			Lambdacyhalothrin 0.05%			DDT 4%		
	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
Plateau	95 (92)	97 (100)		96.8 (94)	74 (100)		100 (89)	84 (100)		84 (95)	88 (100)		63 (95)	43 (100)
Jigawa	50 (100)			68.6 (86)			87 (76)			63 (88)			41 (78)	
Rivers	73 (75)	58 (100)		76 (75)	40 (100)		70 (60)	98 (100)		75 (75)	48 (100)		63 (60)	37 (100)
Enugu	30 (80)	19 (100)		84 (80)	84 (100)		66 (80)	68 (100)		50 (80)	13 (100)		31 (80)	6 (100)
Nassarawa	81 (80)	50 (100)	33	97.5 (80)	85 (100)	100	99 (80)	89 (100)	28	32 (80)	35 (100)	9	9 (80)	8 (100)
Lagos	77 (100)	3 (100)		92 (100)	7 (100)		93 (100)	96 (100)		69 (100)	12 (100)		17 (100)	1 (100)
Doma		10 (100)	44		59 (100)	80		85 (100)	37		23 (100)	9		7 (100)
Sokoto		30 (100)			83 (100)			68 (100)			12 (100)			70 (100)

WHO tube assays for *An. gambiae* s.l., 2013-2015: Carbamates and organophosphates

Region	Bendiocarb 0.1%			Propoxur 0.05%		Fenitrothion 1%	Pirimiphos-methyl 0.25%	
	2013	2014	2015	2014	2015	2013	2014	2015
Plateau		100 (90)	100 (100)	99 (90)	95 (100)		71 (84)	74 (100)
Jigawa		100 (70)		99 (93)			62 (95)	
Rivers		100 (75)	100 (100)	100 (75)	78 (100)		65 (75)	59 (100)
Enugu		100 (80)	100 (100)	100 (80)	95 (100)		66 (80)	52 (100)
Nassarawa	100	100 (80)	100 (100)	100 (80)		100	46 (80)	95 (100)
Lagos		100 (100)	100 (100)		98 (100)		98 (100)	100 (100)
Doma	100		100 (100)			100		100 (100)
Sokoto			73 (100)					63 (100)

PMI Insecticide Susceptibility Summaries

An. gambiae s.l. Deltamethrin intensity assay: 1x-10x

Site	1X %mortality	2X %mortality	5X %mortality	10X %mortality
Lagos	66	82	89	94
Enugu	88	100	100	100
Nasarawa	99	100	100	100
Plateau	74	77	84	93
Rivers	71	75	89	95
Sokoto	87	98	88	100

An. gambiae s.l. Deltamethrin CDC bottle synergist assay results:

District	Exposure time (min)	Deltamethrin	Deltamethrin + PBO
Lagos	30	64	90
Nassarawa	30	99	100
Doma	30	98	100

PMI Insecticide Susceptibility Summaries

RWANDA

PMI is the sole supporter of seasonal IRS in Rwanda, although the Government of Rwanda and the Global Fund have, on occasion, supported IRS for epidemics. The PMI IRS program in Rwanda was launched in 2007, with three districts (Gasabo, Nyarugenge, and Kicukiro) in Kigali Province that were blanket sprayed. In 2008, the two districts of Kirehe and Nyanza were added. However, focal spraying was used, targeting high malaria burden sectors. In 2009, the districts of Bugesera and Nyagatare were added for a total of 7 districts. In 2011 IRS was withdrawn from Kigali based on epidemiological and entomological data. Gisagara, Bugesera, Kirehe, Nyanza, and Nyagatare districts were sprayed. In 2012, IRS was scaled back to blanket spraying in 3 districts (Bugesera, Gisagara, and Nyagatare), and has continued in those districts through 2014. The second round of IRS in 2015 added the district of Kirehe.

Spraying generally occurs in two rounds, to cover the 8-month transmission season. In 2011-2012, pyrethroids were used. In 2013 a combination of pyrethroids and carbamates were used, and only carbamates were used in 2014. For IRS in 2015 and early 2016, carbamates were used. A switch to organophosphates is planned for the second round of 2016.

COMMENTS ON DATA:

Susceptibility data was collected in collaboration with the National Malaria Control Program. *An. gambiae* s.l. larvae were collected from field sites and reared to adults for testing. Numbers tested were not reported. Molecular identification conducted on 188 *An. gambiae* s.l. which were sampled from January-March 2016 showed 140 (74.5%) were *Anopheles arabiensis* and the remaining 48 (25.5%) were *Anopheles gambiae* s.s.

Synergist data was collected in 2015.

CONCLUSIONS:

- The most recent data shows widespread *An. gambiae* s.l. resistance to pyrethroids and DDT, although a few districts do still show 100% susceptibility.
- Probable *An. gambiae* s.l. resistance to carbamates in Nyagatare and Bugesera has been reported; 2011 data shows probable resistance in Nyamasheke, Gicumbi, and Kirehe, but these sites have not been retested. Carbamates show full susceptibility in all other tested districts.
- *An. gambiae* s.l. shows full susceptibility to organophosphates.
- Tests using *An. gambiae* s.l. that were pre-exposed to PBO showed fully restored susceptibility to permethrin and deltamethrin across sites in Bugesera and Kayanza.

PMI Insecticide Susceptibility Summaries

An. gambiae s.l. WHO tube assay results for pyrethroids and DDT. For 2011 data, 80-100 mosquitoes were used, for 2012-13 data, numbers were not reported. 2014-2015 data was reported by district only.

District	Site	Deltamethrin 0.05%				Lambdacyhalothrin 0.05%				Permethrin 0.75%			Etofenprox 0.5%	DDT 4%		
		2011	2012	2013	2014-2015	2011	2012	2013	2014-2015	2011	2013	2014-2015	2013	2011	2012	2013
Nyagatare	Nyagatare			82	81			74	80		76	92	76			99
	Mimuli	98	23	81		100	20	57		86	66		82	76	84	95
Bugesera	Mwogo			88	67,			85			90		80			99
	Rilima			99	58, &			95	43, 46		98	63, 41	97			100
	Mareba	99	90	90	97	100	86	86	& 86	99			95	99	97	97
Gisagara	Kirarambogo			58	90			35	92, 66		50	95, 84	64			51
	Gakoma			94				90			89		94			100
Nyanza	Busoro	100		87		100		77		100	95		90	100		89
Rusizi	Mashesha	100		97		95		88		90	89		90	91		88
	Nkanka			99				96			97		100			99
Rutsiro	Kivumu	100	100			100	97			100				95	100	
Musanze	Rwaza		99				98								99	
Karongi	Mubuga	99	97			100	90			97				96	97	
Nyamagabe	Mbuga	97				100				95			100			
Nyamasheke	Nyamasheke	93				99				89			75			
Kayonza	Rukara	94				100				84						
Gicumbi	Rubaya	100				100				100			100			
Musanze	Musanze	99				100				100				96		
Kirehe	Bukora	88				99				84				80		
Ruhango	Karambi	99				100				91				97		
Kicukiro	Kicukiro	90				100				99				52		

PMI Insecticide Susceptibility Summaries

An. gambiae s.l. WHO tube assay results for organophosphates and carbamates. For 2011, 80-100 mosquitoes were used, for 2012-2013, numbers were not reported. 2014-2015 data was reported by district only. *Concentration unknown

District	Site	Bendiocarb 0.1%				Fenitrothion 1%				Pirimiphos-methyl*
		2011	2012	2013	2014-2015	2011	2012	2013	2014-2015	2014-2015
Nyagatare	Nyagatare			100	100			100	100	100
	Mimuli	94	84	100		100	100	100		
Bugesera	Mwogo			93	100			100	100	100
	Rilima			97		100	100	100		
	Mareba	100	100	100		100	100	100		
Gisagara	Kirarambogo			100	100			100	100	100
	Gakoma			99		100	100	100		
Nyanza	Busoro	100		100		100	100			
Rusizi	Mashesha	100		100		99	100			
	Nkanka			100			100			
Rutsiro	Kivumu	96	99			100	100			
Musanze	Rwaza		100				100			
Karongi	Mubuga	98	98			100	100			
Nyamagabe	Mbuga	99				99				
Nyamasheke	Nyamasheke	96				99				
Kayonza	Rukara	99				100				
Gicumbi	Rubaya	100				100				
Musanze	Musanze	91				100				
Kirehe	Bukora	91				100				
Ruhango	Karambi	99				100				
Kicukiro	Kicukiro	100				100				

PMI Insecticide Susceptibility Summaries

2015: Synergist testing of pyrethroids against *An. gambiae* s.l. using the CDC bottle assay

District	Site	Insecticide	Mortality %	
			Insecticide	Insecticide + PBO
Nyaruguru	Ngera	D-deltamethrin (0.05%)	58	100
		P-permethrin (0.75%)	40	91
Kirehe	Bukora	D-deltamethrin (0.05%)	67	100
		P-permethrin (0.75%)	54	97
Bugesera	Mareba	D-deltamethrin (0.05%)	67	100
		P-permethrin (0.75%)	63	100
	Gashora	D-deltamethrin (0.05%)	58	100
		P-permethrin (0.75%)	41	100
	Ruhuha	D-deltamethrin (0.05%)	91	100
		P-permethrin (0.75%)	78	100
Kayonza	Rukara	D-deltamethrin (0.05%)	79	100
		P-permethrin (0.75%)	73	100

PMI Insecticide Susceptibility Summaries

SENEGAL

PMI is the sole supporter of IRS in Senegal. From 2007 to 2009, PMI supported IRS campaigns in the health districts of Vélingara, Nioro, and Richard Toll, with each district representing one of the country's three ecological zones. In 2010, the IRS program was expanded to three additional districts: Guinguinéo, Malem Hodar, and Koumpentoum. In 2011, spraying in Richard Toll was suspended due to low malaria prevalence. In 2013-2014, four districts were sprayed: Malem Hoddar, Koungheul, Koumpentoum and Vélingara. In 2015, 4 districts received focalized IRS, with a slight shift to include: Malem Hoddar, Koungheul, Koumpentoum, and Nioro.

From 2008-2010, pyrethroids were used for IRS. In 2011, the program transitioned to carbamates, spraying a carbamate in five districts, and leftover deltamethrin from the last spray round in two districts. Carbamates were used in 2012-2013, and a combination of carbamates and organophosphates was used from 2014-2015.

COMMENTS ON DATA:

Tests were conducted on *An. gambiae* s.l. mosquitoes reared from field-collected larvae.

The *kdr* mutation has been found in *An. gambiae* S form (14-18.6%) and *An. arabiensis* (3-12%). The mutation was not found to be present in *An. funestus* or *An. gambiae* M form (from June 2011 "Profil entomologique du paludisme au Senegal").

CONCLUSIONS:

- Resistance to pyrethroids has been seen in most districts. Interestingly, in some sites pyrethroid resistance decreased after pyrethroid IRS was removed, but not to complete susceptibility.
- There is either probable or confirmed resistance to organochlorines (DDT and dieldrin) in all sites.
- There are several regions where bendiocarb resistance was reported: including Dakar, Kaolack, and Thies.
- There is full susceptibility to organophosphates in all areas, with the exception of probable resistance to fenitrothion in Kedougou, Kolda, Tambacounda, and Pikine districts. Malathion showed possible resistance in Guediawaye and Niayes. There is 99-100% susceptibility to pirimiphos-methyl in all sites.
- Synergist assays did not affect susceptibility to DDT and partially restored susceptibility to permethrin in 2015 tests using *An. gambiae* s.l.

PMI Insecticide Susceptibility Summaries

An. gambiae s.l., WHO tube assays for pyrethroids

District	Region	Deltamethrin 0.05%			Lambdacyhalothrin 0.05%			Permethrin 0.75%			Alphacypermethrin 0.1%		
		2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
Dakar Centre	Dakar		89.4			85.8			75.7			85.8	
Guediawaye	Dakar		43.4	47 (100)		38.7	17 (100)		5	3 (100)		69.4	43 (100)
Pikine	Dakar		50	62 (100)		59.3	23 (100)		23.3	22 (100)			64 (100)
Bambey	Diourbel		87.1	86 (100)			85 (100)	98 (102)	77.7	85 (100)			81 (100)
Fatick	Fatick			77 (100)			88 (100)	100 (105)	99.1	80 (100)			84 (100)
Niakar	Fatick	100 (107)		90 (100)			94 (100)	100		94 (100)			92 (100)
Kaffrine	Kaffrine	88 (102)	98		67 (99)	64		91	91		73 (106)	84.8	
Koungheul	Kaffrine	100 (83)	100	85 (100)		84.9	98 (100)	96 (84)	96.5	92 (100)	88 (81)	96	100 (100)
Maleme Hodar	Kaffrine	78 (108)	85	60 (100)	55 (100)	71		89 (103)	82	47 (100)	93 (96)	84.7	
Guinguineo	Kaolack			95 (100)				70 (102)		84 (100)	70 (98)		
Ndoffane	Kaolack	88 (103)	81.9	88 (100)	89 (103)	70.1		59 (98)	45.3	60 (100)	90 (106)		
Nioro	Kaolack	98 (102)	80.1	83 (100)	97 (110)	76.4	82 (100)	70 (90)	46.2	64 (100)	93 (101)		97 (100)
Kedougou	Kedougou		72			64.1			45			53.9	
Kolda	Kolda		49						60			67.8	
Velingara	Kolda		86.5	88 (100)			77 (100)	74 (76)		92 (100)	94 (53)		90 (100)
Barkédji	Louga		87.8						100				
Gabou (Bakel)	Matam		92										
Kanel	Matam		98.8										
Ranerou	Matam		96.2										
Richard Toll	St. Louis	88.3	91.4	78 (100)	71.7	97.2	100 (100)	79.4	78.2	23 (100)	94 (105)	94.7	
Koumpentoum	Tambacounda		83	63 (100)		75.2	56 (100)	100 (76)	80.4	77 (100)	83 (77)	84.1	84 (100)
Tambacounda	Tambacounda		68			36			50			82	
Mbour	Thies			69 (100)			91 (100)	79 (104)	94.5	89 (100)			86 (100)
Medina Fall	Thies	94 (110)											
Ndioukhane	Thies	89 (96)	92.2					76 (75)			68 (76)	91.9	
Niayes	Thies		83.9	52 (100)		49.5	64 (100)		78.2	38 (100)		90.9	68 (100)
Thilane	Thies	94 (100)						95 (83)			95 (80)		

PMI Insecticide Susceptibility Summaries

An. gambiae s.l. WHO tube assays, organochlorines and carbamates

District	Region	DDT 4%			Dieldrin 4%			Bendiocarb 0.1%		
		2013	2014	2015	2013	2014	2015	2013	2014	2015
Dakar Centre	Dakar		13.9			7.8			8.7	
Guediawaye	Dakar		1.9	1 (100)		18.1	32 (100)		64.1	35 (100)
Pikine	Dakar		0.9	1 (100)			14 (100)		34	63 (100)
Bambey	Diourbel	75	39	70 (100)			97 (100)	99 (99)	100	100 (100)
Fatick	Fatick	88		53 (100)			99 (100)	100 (103)	100	100 (100)
Niakar	Fatick	75					94 (100)	100 (114)		100 (100)
Kaffrine	Kaffrine	77	80		92 (92)	95.9		83 (96)	100	
Koungheul	Kaffrine	85	78.4	91 (100)		97	100 (100)	100 (87)	100	100 (100)
Maleme Hodar	Kaffrine	90	87	65 (100)	97.8	93.8		100 (120)	100	100 (100)
Guinguineo	Kaolack	64.8	67	64 (100)				99 (108)	100	
Ndoffane	Kaolack	68.6	44.8	43 (100)	87 (100)	78.8		78 (213)	95.3	96 (100)
Nioro	Kaolack	82.1	73.2	79 (100)	92 (106)		93 (100)	99 (103)	100	100 (100)
Kedougou	Kedougou		13			75			92.5	
Kolda	Kolda		19						92.4	
Velingara	Kolda	92	77.3	83 (100)			92 (100)	100 (79)	95.4	99 (100)
Barkédji	Louga		88.3						100	
Kanel	Matam		82.7						88.9	
Richard Toll	St. Louis	41.4	86.9	54 (100)	72 (104)	92.7		86 (101)	100	
Koumpentoum	Tambacounda		86.7	74 (100)	92 (93)		98 (100)	100 (82)	99	99 (100)
Tambacounda	Tambacounda		54			83			93	
Mbour	Thies		80.7	36 (100)			92 (100)	94 (96)	98	100 (100)
Medina Fall	Thies	31						100 (99)		
Ndioukhane	Thies	47	43.2			77.9		100 (76)	93.3	
Niayes	Thies	54	37.2	28 (100)			48 (100)	98 (112)	86.7	90 (100)
Thilane	Thies	65								
Oussoye	Ziguinchor							100		

PMI Insecticide Susceptibility Summaries

An. gambiae s.l. WHO tube assays, organophosphates

District	Region	Fenitrothion 1%			Malathion 5%			Pirimiphos-methyl 1%		
		2013	2014	2015	2013	2014	2015	2013	2014	2015
Dakar Centre	Dakar		100			100			100	
Guediawaye	Dakar		100	100 (100)		100	74 (100)		100	100 (100)
Pikine	Dakar		100	95 (100)			100 (100)			100 (100)
Bambey	Diourbel			100 (100)			100 (100)	100 (102)	100	100 (100)
Dioffior	Fatick								100	
Fatick	Fatick			100 (100)			100 (100)	100 (101)		100 (100)
Niakar	Fatick			100 (100)			100 (100)	100 (119)		100 (100)
Kaffrine	Kaffrine	100 (100)	100		100 (106)	100		100 (99)	100	
Koungheul	Kaffrine	100 (90)	100	100 (100)		100	100 (100)	100 (92)		95 (100)
Maleme Hodar	Kaffrine	100 (98)	100		100 (99)	100	100 (100)	100 (91)	100	100 (100)
Guinguineo	Kaolack	100 (105)					100 (100)	100 (105)	100	
Ndoffane	Kaolack	100 (102)			100 (107)	100		100 (104)		100 (100)
Nioro	Kaolack	100 (112)		100 (100)	100 (105)	100	100 (100)	100 (110)		100 (100)
Kedougou	Kedougou		94.5			99				
Kolda	Kolda		97.9			100				
Velingara	Kolda	100 (82)		100 (100)			100 (100)	100 (78)		99 (100)
Barkédji	Louga								100	
Gabou (Bakel)	Matam								98.9	
Kanel	Matam								100	
Richard Toll	St. Louis	100 (107)	100		100 (107)	100	100 (100)	100 (110)		
Koumpentoum	Tambacounda			100 (100)		100	100 (100)	100 (88)		100 (100)
Tambacounda	Tambacounda		97			99				
Mbour	Thies			100 (100)			99 (100)	100 (94)	100	100 (100)
Medina Fall	Thies							100 (99)		
Ndioukhane	Thies	100 (71)	100			100		100 (66)	100	
Niayes	Thies		100	100 (100)		100	94 (100)	100 (106)		99 (100)
Thiès	Thies									
Thilane	Thies	100 (93)						100 (80)		

PMI Insecticide Susceptibility Summaries

An. gambiae s.l. CDC bottle synergist assay data from 2015

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)

PMI Insecticide Susceptibility Summaries

TANZANIA

PMI launched IRS on mainland Tanzania in 2007, in Muleba and Karagwe districts in Kagera Region. In 2009, PMI expanded spraying to cover the remaining 5 districts of Kagera Region. In 2010 and 2011, IRS expanded to include the 6 districts of Mwanza Region and 5 districts of Mara Region for a total of 18 districts in the Lake Zone. In 2012, IRS was moved from blanket to targeted spraying in some districts, and in 2013 IRS was scaled down to 15 districts in the Lake Zone. In 2014, 16 districts in the Lake Zone were sprayed. Pyrethroids were used up to 2011; a combination of pyrethroids and carbamates was used in 2011-2013; organophosphates were used in 2013 and 2014. In 2015, Mwanaxa and Mara were targeted for IRS with organophosphates and in 2016, the IRS campaign broadened to include 8 sites on the Mainland, all of which were sprayed using organophosphates.

Starting in 2006 Zanzibar conducted IRS with pyrethroids. A combination of pyrethroids and carbamates was used in 2012 and 2013, and organophosphates were used from 2014-2016.

COMMENTS ON DATA:

Susceptibility data was collected in collaboration with the National Institute for Medical Research, Amani Medical Research Centre and Mwanza Center, as well as the Zanzibar Malaria Control Program (ZMCP). Reports from 2013-2015 did not include specified number of mosquitoes tested only that four batches of 15-25 were used for testing. Data for 2016 includes number of mosquitoes tested for each insecticide, but these data are provisional and subject to change.

Mainland:

In 2013, 1,623 *An. gambiae* s.l. were tested for species ID by PCR, and were identified as 84.7% *An. arabiensis*, 8.4% *An. gambiae* s.s., and 0.7% *An. quadriannulatus*. *An. gambiae* s.s. was found only in Singida rural (100% of samples) and Bagamoyo (13% of samples); *An. quadriannulatus* was found only in Mbozi (9% of samples), while *An. arabiensis* was the predominant species in all other areas. 577 *An. gambiae* s.l. were tested for *kdr*. The L1014S mutation was found only in Kinondoni (0.17 gene frequency), while the L1014F mutation was not seen. Elevated levels of MFOs and esterases were seen in samples from Moshi, but not other sites.

Zanzibar: In 2013/2014, 1,015 samples were investigated for the *kdr* mutation and no specimens were found positive. For the same timeframe, molecular identification of mosquito species in Unguja reported: 49% *An. gambiae*, 44% *An. arabiensis*, 6% *An. merus*. In Pemba, the molecular identification results showed: 93% *An. arabiensis*, 1% *An. gambiae*, 1% *An. merus*.

PMI Insecticide Susceptibility Summaries

Mainland WHO tube assays for *An. gambiae* s.l.: pyrethroids and DDT. 2014-2016 data are from NIMR with PMI funding support. 2016 Data are provisional and may be updated.

Mainland	Permethrin 0.75%			Lambdacyhalothrin 0.05%		Deltamethrin 0.05%			DDT 4%	
	2014	2015	2016	2013	2014	2014	2015	2016	2013	2015
Kilombero	100	58	90 (100)	100	25	59	66	63 (100)	100	93
Kyela	100		91 (75)	93	100	100		89 (75)	100	
Muheza	77.8			72	89	98			96	
Arumeru	45	57	37 (120)	34	49	92	63	31 (124)	100	99
Magu (Mwanza Region)	100	93		78	76	97.5	82		100	100
Muleba (Kagera Region)		70	44 (81)				61	39 (80)		87
Babati	100	65		65	38	74	84		100	100
Moshi		19		57			33		98	100
Manyoni		100					93			100
Ngara (Kagera Region)	100	100	98 (75)	100	83	90	100	100 (75)	100	100
Geita (Mwanza Region)	98	98	96 (80)		93	97	99	100 (80)		80
Bagamoyo	90	95	42 (100)	41	86	100	78	54 (100)	100	59
Kahama	100	97			51	86	85		100	100
Kilosa	100	100			64	72	100		97	71
Kinondoni	92.5	100			85	70	100		84	91
Kasulu									96	
Kondoa	100	39			100	100	57		100	100
Mbozi	93	100			89	93	100		100	100
Musoma R	95	60	100 (80)			99	81	97 (80)	100	100
Singida									100	
Uyui									100	
Iringa	100	97			100	100	98			100
Mtwara		100					100			
Ruangwa	100	100	17 (100)		100	100	100	32 (100)		100
Songea	100	100			100	100	100			100
Sengerema			66 (80)					92 (80)		

PMI Insecticide Susceptibility Summaries

Mainland WHO tube assay data, *An. gambiae* s.l.: carbamates and organophosphates. 2014-2016 data are from NIMR with PMI funding support. 2016 Data are provisional and may be updated.

Mainland	Bendiocarb 0.1%				Fenitrothion 1%	Pirimiphos-methyl 0.25%	
	2013	2014	2015	2016	2013	2015	2016
Kilombero	100	100	100	100 (100)	100	100	100 (100)
Kyela	82	100		94 (80)	87		100 (75)
Muheza	100	100					
Arumeru	97	58	98	66 (96)	100	87	87 (97)
Magu (Mwanza Region)	100	100	100		100	95	
Muleba (Kagera Region)			100	61 (81)		86	100 (80)
Babati	100	100	100		100	94	
Moshi	100		100		100	100	
Sumbawanga							
Manyoni			100			100	
Ngara (Kagera Region)	100	100	100	100 (75)	100	100	97 (70)
Geita (Mwanza Region)		98	100	100 (80)		83	100 (80)
Tarime							
Bariadi							
Kigoma							
Bagamoyo	100	100	99	100 (100)	100	100	100 (100)
Kahama	100	100	100		100	98	
Kilosa	100	100	100		100	100	
Kinondoni	100	92.5	100		100	100	
Kasulu	100				100		
Kondoa	96	100	100		100	100	
Mbozi	100	93	100		100	100	
Musoma R	100		100	100 (80)	100	100	100 (80)
Singida	99				100		
Uyui	100				100		
Iringa		100	100			100	
Mtwara			100			100	
Ruangwa		100	100	99 (100)		100	100 (100)
Songea		100	100	100 (100)		100	99 (80)

PMI Insecticide Susceptibility Summaries

Sites	Lambdacyhalothrin 0.05%			Permethrin 0.75%			Alphacypermethrin 0.05%	Deltamethrin 0.05%		
	2012	2013	2014	2012	2013	2014	2014	2012	2013	2014
Pemba Island										
Bopwe						53	33			
Bopwe/mangwena chwale	48.9					71				
Kisiwa Panza			73							
Machengwe				22						
Minungwini		13							13	
Msuka										
Pujini		18.3	34		76	55	31			43
Tibirinnzi			77							
Tumbe	37.2	77.1			63	73.5		39		
Uwandani	27	82	45	49	36	49	40			49
Unguja Island										
Cheju		75			98			88		
Chuini	81.9	69.3								
Kianga				97						
Kilimani		57.1								
Kirombero			77							
Mwera	88.4	74.5			71.8		88			
Uzini						39				

Sites	Bendiocarb 0.1%			Pirimiphos-methyl 0.25%	
	2012	2013	2014	2013	2014
Pemba Island					
Bopwe					
Bopwe/mangwena chwale			100		
Kisiwa Panza					
Machengwe					
Minungwini		100		100	
Msuka			100		
Pujini		100	100		100
Tibirinnzi					
Tumbe					
Uwandani	100	100	100		
Unguja Island					
Cheju			100	100	100
Chuini	100				
Kianga					
Kilimani					
Kirombero					
Mwera		100	100		100
Uzini					

PMI Insecticide Susceptibility Summaries

CONCLUSIONS:

- For Zanzibar: *An. gambiae* s.l. is resistant to pyrethroids, but fully susceptible to bendiocarb and pirimiphos-methyl
- For Mainland Tanzania:
 1. *An. gambiae* s.l. is resistant to at least one pyrethroid in half of the sites tested; however, resistance varies highly between specific pyrethroids and by year, from 34-100% mortality.
 2. There is DDT resistance in Kinondoni, Bagamoyo and suspected resistance in 6 additional sites.
 3. There is evidence of resistance to bendiocarb in Magu and Muleba with probably resistance in Kyela. Additionally, emerging resistance to pirimiphos-methyl has been observed at 6 sites, and confirmed at Arumeru where no IRS has been conducted. Full susceptibility to fenitrothion was reported in 2013, but has not been recently tested.

PMI Insecticide Susceptibility Summaries

UGANDA

IRS in Uganda is funded by the Department for International Development (DFID) and implemented through PMI. In 2006, PMI supported a large-scale IRS program in the epidemic-prone southwestern highland district of Kabale. In 2007, PMI targeted its support to high-risk sub-counties of Kabale and extended support to the neighboring district of Kanungu and four northern districts (Kitgum, Pader, Gulu, and Amuru). From 2009-2014, PMI supported IRS in 10 high-transmission districts in northern Uganda (Kitgum, Agago, Lamwo, Pader, Amuru, Nwoya, Gulu, Oyam, Kole, Apac). After a LLIN universal coverage campaign in 2014, IRS shifted to the southeast of Uganda. In 2015, PMI transitioned to nine new IRS districts to the southeast (Iira, Tororo, Butaleja, Namututmba, Kibuku, Budaka, Pallisa, Bugiri and Serere). In addition, DFID funding provided to PMI in 2015 supported IRS operations in five contiguous districts (Alebtong, Dokolo, Amolatar, Kaberamaido, and Otuke). Each district was blanket sprayed twice in 2015 with a carbamate insecticide.

Starting in 2008, IRS was initially conducted in two rounds per year, using pyrethroids in all districts except Apac and Oyam, which used DDT. Due to insecticide resistance, IRS was changed to carbamates from 2010-2015.

COMMENTS ON DATA:

2013, 2015: Both *An. gambiae* s.l. reared from field-collected larvae and adult mosquitoes were used.

CONCLUSIONS:

- There are high levels of resistance to both DDT and pyrethroids in all districts tested.
- There is susceptibility to organophosphates in all districts (both malathion and pirimiphos-methyl).
- There is probable resistance to carbamates in Kanungu, Hoima, and Tororo. In Wakiso, there is confirmed resistance to bendiocarb, and suspected resistance to propoxur. Follow up testing in 2015, did not show continuity with respect to emerging resistance to carbamates, data show full susceptibility at all testing sites.
- Synergist testing reported increased susceptibility to deltamethrin but only partially for permethrin.
- Intensity data regarding deltamethrin and permethrin show increased susceptibility with increasing insecticide concentration.

PMI Insecticide Susceptibility Summaries

An. gambiae s.l., WHO tube assay results: pyrethroids. (A) indicates mosquitoes from adult collections were used, (L) indicates larval collections.

District	Lambdacyhalothrin 0.05%		Permethrin 0.75%		Deltamethrin 0.05%		Alphacypermethrin 0.05%		Etofenprox 0.5%
	2013	2015	2013	2015	2013	2015	2013	2015	2013
Apac	56 (100 L)		85 (100L)	14 (100 L)	82 (100 L)	22 (100 A)			84 (100 L)
Kitgum					58 (100 L)				
Wakiso	21 (100 L)		24 (100 L)	40 (100 A)	44 (100 A)	73 (100 A)	60 (100 A)		
Kanungu	27 (100 A)	9 (100 A)	31 (100 A)	22 (100 A)	53 (100 A)	51 (100 A)	61 (100 A)	33 (100 L)	
Hoima					18 (100 L)				
Tororo	26 (100 L)		45 (100 A)	67 (100 A)	37 (100 L)	82 (100 A)	42 (100 A)		
Lira				19 (100 A)		59 (100 A)			
Soroti				61 (100 L)		87 (100 A)			

An. gambiae s.l., WHO tube assay results: organochlorines, carbamates, and organophosphates. (A) indicates mosquitoes from adult collections were used, (L) indicates larval collections.

District	DDT 4%		Propoxur 0.1%		Bendiocarb 0.1%		Malathion 5%	Pirimiphos-methyl 1%	
	2013	2015	2013	2015	2013	2015	2013	2013	2015
Apac	95 (100 L)				99 (100 L)	100 (100 A)		100 (130 L)	
Kitgum	81 (100 L)				100 (100 L)			100 (100 L)	
Wakiso	10 (100 L)		92 (100 A)		85 (100 L)		100 (75 A)	100 (100 L)	
Kanungu	59 (100 A)	77 (100 L)	100 (100 A)	100 (100 A)	100 (100 A)	100 (100 A)		100 (80 L); 100 (100 A)	100 (100 A)
Hoima	34 (100 L)				95 (100 L)			100 (100 L)	
Tororo	41 (100 A); 37 (100 L)		95 (100 A)		94 (115 A); 100 (100 L)	100 (100 A)	100 (50 A)	100 (100 L); 100 (109 A)	
Lira						100 (100 A)			
Soroti						100 (100 A)			

PMI Insecticide Susceptibility Summaries

CDC bottle bioassay synergist data reported for *An. gambiae* s.l. and *An. funestus* 2014-2015. *Testing with deltamethrin and PBO synergist was repeated twice in Lira in 2015

	Districts	Deltamethrin				Permethrin			
		2014		2015		2014		2015	
		Deltamethrin	Delta +PBO	Deltamethrin	Delta + PBO	Permethrin	Perm + PBO	Permethrin	Perm + PBO
<i>An. gambiae</i> s.l.	Apac							30	79
	Lira			64, 45	100, 95				
	Kanungu			51	96			23	84
	Soroti			84	100				
	Tororo	18 (102)	98 (108)	78	98				99
	Wakiso			73	100			40	100
<i>An. funestus</i>	Apac							4	77
	Lira	63 (105)	100 (105)			81 (105)	53 (40)		

2015 resistance intensity data for deltamethrin and permethrin; *An. funestus* tested in Apac – all other sites were *An. gambiae* s.l.

DISTRICT	INSECTICIDE	INSECTICIDE CONCENTRATION/% VECTOR MORTALITY			
		1X	2X	5X	10X
Apac	Permethrin	56	76	89	100
	Deltamethrin	63	80	90	100
Hoima	Permethrin	48	86	95	100
Kanungu	Permethrin	19	32	83	97
	Deltamethrin	76	83	89	100
Kitgum	Deltamethrin	90	90	100	100
Wakiso	Permethrin	80	92	96	100
	Deltamethrin	88	96	100	100

PMI Insecticide Susceptibility Summaries

ZAMBIA

The government of Zambia began implementing IRS in 2003. In 2007 and 2008, PMI-supported IRS was conducted in 15 districts in 5 provinces. In 2009, it was expanded to 36 districts, covering all 9 provinces. In 2010, IRS supported by PMI and other donors sprayed 54 districts nationwide. In the 2011 spray season all 72 districts had IRS activities. In 2012-2013, PMI supported spraying in 20 districts, while the government covered remaining districts. In 2014, PMI supported IRS in: Chadiza, Chipata, Katete, Lundazi, Mambwe, Nyimba, Petauke (Eastern Province); Chama, Chinsali, Isoka, Mpika, Nakonde (Muchinga Province); Chilube, Kaputa, Kasama, Mbala, Mporokoso, Mpulungu, Mungwe, Luwingu (Northern Province). In 2014 PMI also sprayed an additional 9 districts with DfID support: Mansa, Samfya, Mwense, Milengi, Kawambwa, Nchelenge, Chienge (Luapula Province); Serenje and Mkushi (Central Province). In 2015, PMI-supported IRS was conducted in 25 districts and DFID managed IRS activity in an additional 14 districts.

IRS in Zambia was performed using a combination of DDT and pyrethroids until 2011. In 2011, a combination of pyrethroids, carbamates, and organophosphates were used based on local insecticide resistance data. In 2012 PMI-supported IRS was conducted using a carbamate and an organophosphate, and in 2013-2015 was transitioned to organophosphate only.

COMMENTS ON DATA:

Data from 2014 and 2015 were collected by the PMI AIRS project with NMCC. Tested mosquitoes were either reared from field-collected larvae or were offspring of field-collected, blood fed adults.

An. gambiae s.s. has been shown to carry the *kdr-west* mutation in Central, Copperbelt, and Northwestern Provinces. Both *An. gambiae* s.s. and *An. funestus* have been tested for metabolic resistance, and both have shown elevated levels of p450s.¹

CONCLUSIONS:

- *An. gambiae* s.l. is highly resistant to pyrethroids throughout all tested sites.
- For *An. gambiae* s.l., there are varying levels of DDT resistance, from very high in Copperbelt, to probable resistance in some parts of Luapula, and susceptibility in other parts of Luapula.
- For *An. gambiae* s.l., there is resistance to bendiocarb in Luapula
- *An. funestus* is mainly resistant to pyrethroids and 100% susceptible to DDT.
- *An. funestus* is resistant or has probable resistance to bendiocarb in most areas.
- Both *An. gambiae* and *An. funestus* are 100% susceptible to pirimiphos-methyl in all tested districts.
- Intensity assays show 5x and 10x resistance to deltamethrin in two districts, while only 1x or 2x resistance was seen for permethrin, alphacypermethrin, and lambdacyhalothrin at the same sites. Where tested, PBO restored deltamethrin susceptibility.
- Initial synergist assays priming with PBO showed increased susceptibility to deltamethrin.

¹ Data from Insecticide Resistance Monitoring Report, prepared by Michael Coleman, LSTM, for ZISSP

PMI Insecticide Susceptibility Summaries

WHO tube assay data, *An. gambiae* s.l., 2014

Province	District	Site	Deltamethrin 0.05%	Permethrin 0.75%	DDT 4%	Bendiocarb 0.1%	Pirimiphos-methyl 0.25%
Central	Serenje	Chibobo	51(25)		86 (25)		100 (50)
Central	Serenje	Chipundu	49.1 (25)		82 (25)		100 (139)
Copperbelt	Masaiti	Chishibambwe					100 (10)
Copperbelt	Masaiti	Kafukanya					100 (8)
Copperbelt	Masaiti	Shimuteya					100 (68)
Luapula	Chiengi	Mwabu Kasenge	41 (75)	38.4 (25)	15.5(25)	92 (25)	100 (25)
Luapula	Chiengi	Mwengeswa	65 (100)	14.6(82)	18.8 (16)	96.8 (95)	100 (109)
Luapula	Kawambwa	Chipota	47 (32)		91(25)	84(25)	100 (25)
Luapula	Kawambwa	Kaweme	59 (38)		98 (25)	99 (52)	100 (81)
Luapula	Mansa	Kateshi	84.4 (55)	35 (40)	99.5 (60)		100 (75)
Luapula	Mansa	Mwa Nguni	68 (25)	18.5 (95)	97 (50)	90 (30)	100 (75)
Luapula	Mansa	Nsenama				88.9 (27)	100 (25)
Luapula	Milenge	Chipe	29.8 (47)		86 (100)	100 (50)	100 (100)
Luapula	Milenge	Katena	69.6 (69)	54.2 (24)	88 (100)	97.2 (100)	100 (50)
Luapula	Milenge	Lunga	71(50)		70.3 (37)	100 (25)	100 (128)
Luapula	Milenge	Talayi	50.8 (100)		92 (52)	100 (25)	100 (82)
Luapula	Mwense	Chongo	35.1 (97)	20.7 (72)	87 (100)	100 (24)	100 (108)
Luapula	Mwense	Kashiba	63 (65)	50 (30)	92 (50)	80 (85)	100 (125)
Luapula	Mwense	Lubunda	72.5 (44)		90 (60)	98 (100)	100 (100)
Luapula	Mwense	Mambilima	70 (40)		96 (100)	82.3 (51)	100 (72)
Luapula	Samfya	Chilumba	43.3 (60)				100 (25)
Luapula	Samfya	Kantashya	87.3 (25)	57.9 (19)	92(50)	100 (25)	100 (100)
Luapula	Samfya	Maximo	69.3 (49)	65.4 (50)	83 (100)	98 (100)	100 (50)
Muchinga	Chinsali	Mikuwe					100 (34)
Muchinga	Isoka	Malekani					100 (89)
Northern	Kasama	Chishimba					100 (62)
Northern	Mbala	Chiunga			32.5 (40)		100 (97)
Northern	Mpulungu	Njeleka			23.8 (80)		100 (69)
Northern	Mungwi	Chitimukulu				100 (80)	100 (100)

PMI Insecticide Susceptibility Summaries

WHO tube assay data, *An. funestus* s.l., 2014-2015

Province	District	Settlement	Deltamethrin 0.05%		Permethrin 0.75%	DDT 4%		Bendiocarb 0.1%		Pirimiphos-methyl 0.25%	
			2014	2015	2014	2014	2015	2014	2015	2014	2015
Central	Mkushi	Twatasha	100 (54)		42 (50)	100 (37)		81.5 (27)		100 (34)	
Central	Serenje	Chibobo	60 (30)	67 (64)	36 (25)	100 (57)	100 (144)	78 (45)	90 (60)	100 (25)	100 (65)
Central	Serenje	Chipundu	68 (25)		60 (30)			84 (50)		100 (11)	
Central	Serenje	Chishi		63.2 (100)			100 (17)				100 (112)
Copperbelt	Masaiti	Chishibambwe								100 (25)	
Copperbelt	Masaiti	Kafukanya								100 (33)	
Eastern	Katete	Mbinga	22.7 (44)							100 (12)	
Luapula	Chiengi	Mwabu Kasenge	53.9 (76)		23(45)	100 (25)		88.4 (69)		100 (40)	
Luapula	Chiengi	Mwengeswa	48.9 (74)		26.7 (69)	100 (25)		76 (64)		100 (89)	
Luapula	Kawambwa	Chipota	72 (44)			100 (30)		77(25)		100 (25)	
Luapula	Kawambwa	Kaweme	64 (25)			100 (40)		55(23)		100 (82)	
Luapula	Mansa	Kateshi	60 (70)		44(25)	100 (50)				100 (25)	
Luapula	Mansa	Mwa Nguni	56(50)		36 (25)	100 (50)		97.5 (80)		100 (128)	
Luapula	Mansa	Nsenama						92.4 (50)		100 (50)	
Luapula	Milenge	Chipe	58 (92)			100 (75)		75(100)		100 (107)	
Luapula	Milenge	Katena	76 (50)			100 (30)		89 (100)		100 (88)	
Luapula	Milenge	Lunga	93.5 (31)	41.5 (41)		100 (25)	100 (50)	89.7 (29)	93 (100)	100 (75)	100 (138)
Luapula	Milenge	Talayi	67 (100)			100 (28)		80 (60)		100 (80)	
Luapula	Milenge	Miyambo					100 (8)		50 (20)		100 (15)
Luapula	Milenge	Mwemamusongo									100 (19)
Luapula	Mwense	Chongo	90.3 (93)		20.8 (72)	100 (72)		84 (45)		100 (15)	
Luapula	Mwense	Kashiba	67.2 (58)		32 (50)	100 (25)		68.5 (73)		100 (90)	
Luapula	Mwense	Lubunda	69 (100)			100 (87)		64.9 (97)		100 (97)	
Luapula	Mwense	Mambilima	73(100)			100 (25)		75 (100)		100 (66)	
Luapula	Mwense	Chebele							100 (31)		100 (33)
Luapula	Mwense	Shibesa		84 (74)							100 (31)
Luapula	Mwense	East farm									100 (50)
Luapula	Samfya	Chilumba				100 (25)				100 (53)	
Luapula	Samfya	Kantashya	91.9 (124)		61(100)	100 (50)		50 (37)		100 (120)	
Luapula	Samfya	Maximo	83(100)		67 (100)	100(48)		85 (60)		100 (46)	
Muchinga	Chinsali	Mikuwe	58 (52)		83 (23)	100 (32)		67 (45)		100 (46)	
Muchinga	Isoka	Kampumbu	92 (46)			100 (50)		80 (42)		100 (42)	
Muchinga	Isoka	Malekani	90 (154)		99.1 (102)	100 (77)		76.1 (160)		100 (118)	
Northern	Kasama	Chishimba	34 (104)		100 (113)	100 (40)		78 (99)		100 (38)	

PMI Insecticide Susceptibility Summaries

Northern	Kasama	Nandola									85.8 (99)			100 (100)
Northern	Kasama	Kalonga									100 (50)			100 (100)
Northern	Kabombeka	Kasama							100 (5)					100 (24)
Northern	Mungwi	Chitimukulu	96 (127)							91 (156)			100 (99)	
Northern	Katate	Robert												100 (40)

An. funestus CDC bottle assays for resistance intensity, and initial synergist testing with deltamethrin. Data are percent mortality when exposed to 1x-10x diagnostic dose.

District	Settlement	Deltamethrin				Deltamethrin +PBO				Permethrin				Alphacypermethrin				Lambdacyhalothrin			
		1x	2x	5x	10x	1x	2x	5x	10x	1x	2x	5x	10x	1x	2x	5x	10x	1x	2x	5x	10x
Milenge	Miyambo	0	0	0	57	100	100	100	100	0	100	100	100	90	100	100	100	83	100	100	100
	Johnny-Nkumba	70	80	70	90					89	100	100	100	40	100	100	100	60	100	100	100
	Shitambulli	75	80	67	100					40	100	100	100								
	Mwewamusongo	67	86	88	100					100	100	100	100								
	Libwete	96	67	75	89					100	100	100									
Samfiya	Pwele	40	60	86	67					100	100	100	100	75	75	100	100	25	100	100	100
	Fumpa kulusa	25	50	67	80					100	100	100	100	83	100	100	100	100	100	100	100

PMI Insecticide Susceptibility Summaries

ZIMBABWE

In 2012, PMI provided technical support to the Government of Zimbabwe's IRS program in 17 districts in 3 provinces (Mashonaland East, Mashonaland West, & Manicaland). In 2013, PMI's technical support for IRS was expanded to 25 districts. For 2014-2015, PMI implemented IRS in 4 districts in Manicaland Province (Nyanga, Mutasa, Chimanimani, and Mutare), while simultaneously providing technical assistance to the NMCP to support IRS operations in the remaining 41 districts of the country.

From 2009 to 2011, a combination of pyrethroids and DDT was used for IRS by the government. Pyrethroids were used in 2012-2013, and organophosphates from 2014-2015. Government-supported IRS outside of Manicaland has used pyrethroids and DDT.

COMMENTS ON DATA:

Susceptibility data was collected by the National Malaria Control Programme (NMCP) and PMI through Abt Associates in collaboration with the National Institute of Health Research (NIHR).

WHO tube assays were performed on *An. gambiae* s.l., with the exception of data from the ICEMR project in Manicaland province, which was on *An. funestus*.

CONCLUSIONS:

- In *An. gambiae* s.l., resistance to pyrethroids is variable, with 100% susceptibility in Mashonaland Central, Midlands, and Mashonaland East, but high lambda-cyhalothrin resistance in Masvingo, Matebeleland South, Matebeleland North, and Mashonaland West. Etofenprox generally performs better than lambda-cyhalothrin.
- *An. gambiae* s.l. is generally susceptible to DDT, with the exception of Masvingo and probable resistance in Matebeleland South.
- There is bendiocarb resistance in *An. gambiae* s.l. in Matebeleland South and Mashonaland West. In 2016, testing reported full susceptibility across all tested sites from 2015, with the only resistant population from Sanyati.
- For *An. funestus* in Manicaland, there is high resistance to all pyrethroids and carbamates, but susceptibility to DDT and pirimiphos-methyl.
- There is 100% susceptibility to pirimiphos-methyl in all sites, both in *An. funestus* and *An. gambiae*.

PMI Insecticide Susceptibility Summaries

2013-2014 WHO tube assay results. All assays were performed on *An. gambiae* s.l., except for Manicaland, where tests were performed on *An. funestus*.

Province	District	Deltamethrin 0.05%		Lambdacyhalothrin 0.05%				Etofenprox 0.5%
		2013	2014	2013	2014	2015	2016^	2014
Mashonaland Central	Rushinga		100 (69)		100 (118)	100 (160)	100 (100)	100 (50)
Masvingo	Chiredzi				100 (102)	100 (148)		100 (24)
Matebeleland South	Beitbridge				86 (113) #	100 (100)	100 (100)	98 (50)
Matebeleland North	Binga				81 (88)	86 (100)	93 (100)	
Midlands	Gokwe South		100 (67)		100 (92)	79.5 (100)	92 (100)	
Mashonaland East	Mutoko	100 (30)	100 (25)	91 (35)	100 (47)		100 (100)	
Mashonaland West	Hurungwe	94 (29)		90 (31)	87 (113)			96 (50)
	Kadoma				72 (90)			
	Sanyati					83 (100)	83 (100)	
Manicaland	Chimanimani						100 (50)	
Manicaland (<i>An. funestus</i>)	Mutasa	65 (49)*		24 (83)*	0 (20)			16 (19)
	Mutare				7 (46)			3 (33)

* is data from the ICEMR project; all other data is from NMCP/PMI through Abt Associates

additional 2014 data shows 100% susceptibility with a sample size of 100

^2016 data- preliminary lab results indicate high proportion *An. quadriannulatus*

PMI Insecticide Susceptibility Summaries

Province	District	DDT 4%			Bendiocarb 0.1%			Pirimiphos-methyl 1%		
		2014	2015	2016^	2014	2015	2016^	2014	2015	2016^
Mashonaland Central	Rushinga	100 (125)	99 (160)	100 (100)	100 (53)	100 (61)	100 (100)	100 (52)	99 (114)	100 (100)
Masvingo	Chiredzi	84 (13)	96 (113)		100 (48)	100 (150)		100 (95)	100 (150)	
Matebeleland South	Beitbridge	91 (207)	90 (100)	85 (100)	100 (107)	84 (100)	100 (100)	100 (100)	100 (100)	96 (100)
Matebeleland North	Binga	100 (88)	98 (100)		100 (89)	99 (100)		100 (93)	100 (100)	
Midlands	Gokwe South	100 (99)	92 (200)	87.5 (100)	100 (98)	97 (100)	100 (100)	100 (110)	100 (100)	100 (100)
Mashonaland East	Mutoko	100 (25)		100 (100)			100 (100)	100 (46)		100 (100)
Mashonaland West	Hurungwe	100 (95)			88 (50)			100 (99)		
	Kadoma	100 (50)			91 (35)			100 (50)		
Manicaland	Sanyati		99 (100)	99 (100)			72 (100)		100 (50)	100 (100)
	Chimanimani			100 (25)			100 (25)			100 (50)
Manicaland (<i>An. funestus</i>)	Mutasa				6 (18)			100 (20)		
	Mutare	100 (36)			23 (26)			100 (30)		

^2016 data - preliminary lab results indicate high proportion *An. quadriannulatus*

Acknowledgements

Abt Associates collected resistance data in Angola, Benin, Ethiopia, Ghana, Liberia, Madagascar, Mali, Mozambique, Nigeria, Rwanda, Uganda, Zambia, and Zimbabwe during 2013-2016.

Additionally, susceptibility data was collected and collated with the help of the following institutions and individuals:

Benin – Professor Martin Akogbeto (CREC)

Burundi – NMCP

DRC – Francis Watsenga (INRB)

Ethiopia – Jimma and Addis Ababa universities

Ghana – Professor Daniel Boakye, Dr. Maxwell Appawu, and Dr. Samuel Dadzie (Noguchi)

Kenya – KEMRI & DOMC

Liberia – NMCP

Madagascar - IPM & PNLP

Malawi – Dr. Themba Mzilahowa (MAC) and NMCP

Mali –MRTC & NMCP

Nigeria – University of Jos; Abubakar Tafawa Balewa University Bauchi; Rivers State University of Science and Technology; Nasarawa State University Keffi; Institute for Advanced Medical Research and Training, College of Medicine, University of Ibadan; National Arbovirus and Vector Research Center Enugu; and Usmanu Danfodiyo University Sokoto

Rwanda – NMCP

Senegal – Lassana Konate, El Hadji Kaba Sylla, Malick Faye Ndao, Amadou Niang, and Ousmane Faye (UCAD)

Tanzania –Amani Medical Research Centre and ZMCP

Uganda –NMCP

Zambia – NMCC

Zimbabwe – NMCP & NIHR