

President's Malaria Initiative Country Insecticide Susceptibility Summaries

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PRESIDENT'S MALARIA INITIATIVE



Introduction

This report summarizes the insecticide susceptibility data that has been collected by the President's Malaria Initiative (PMI) as of the end of January 2015. 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.

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.

WHO has revised their guidelines for the interpretation of WHO susceptibility data. Previously, WHO recommended that >98% mortality in tube bioassays indicated full susceptibility, that 80-97% susceptibility indicated probable resistance, and that <80% mortality indicated resistance to the insecticide being tested.¹ The revised guidelines state that if tests are conducted under ideal conditions (e.g., sample size of >100 mosquitoes, carried out at 25°C ± 2°C and 80% ± 10% relative humidity, replicated 2 or 3 times, and using fresh impregnated papers), then 98-100% mortality indicates susceptibility and <98% mortality indicates that further investigation is required to confirm resistance.²

Resistance is confirmed in one of two ways, depending on percent mortality²:

- 1) If the observed mortality (corrected if necessary) is between 90% and 97%, the presence of resistant genes in the vector population must be confirmed. The confirmation of resistance may be obtained by performing additional bioassay tests with the same insecticide on the same population or on the progeny of any surviving

¹ Test procedures for insecticide resistance monitoring in malaria vectors and bioefficacy and persistence of insecticides on treated surfaces (WHO, 1998).

² Test procedures for insecticide resistance monitoring in malaria vector mosquitoes (WHO, 2012).

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mosquitoes (reared under insectary conditions) and/or by conducting molecular assays for known resistance mechanisms. If at least two additional tests consistently show mortality below 98%, then resistance is confirmed.

- 2) If mortality is less than 90%, confirmation of the existence of resistant genes in the test population with additional bioassays may not be necessary, as long as a minimum of 100 mosquitoes of EACH species was tested. However, further investigation of the mechanisms and distribution of resistance should be undertaken.

The new guidelines will be used in this report, as much of the data was collected after the guidelines were published. 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%). PMI IRS districts from 2014 IRS campaigns are highlighted blue.

If data on resistance mechanisms or resistance intensity 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 100% susceptibility to pirimiphos-methyl. There is a report of resistance to pirimiphos-methyl across multiple sites in Nigeria, which requires confirmation, as this is the first such report in a PMI country.

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

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 100% susceptible to OPs, with the exception of moderate resistance to malathion or fenitrothion in a few sites. There is no resistance to pirimiphos-methyl.

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

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.

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% 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 is the sole supporter of IRS in Angola, which began in 2006. From 2010-2013, PMI supported IRS with deltamethrin 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 are the only insecticides that have been used since PMI began spraying.

COMMENTS ON DATA:

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

CONCLUSIONS:

- Recognizing the caveat that low numbers of mosquitoes have been tested, there appeared to be emerging pyrethroid and carbamate resistance in *An. gambiae* s.l. and *An. coustani*. However, more recent data shows full susceptibility to carbamates and pyrethroids in both species.
- DDT has not been tested on *An. gambiae* s.l. by PMI to date.
- There is full susceptibility to organophosphates.

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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. Data shows % mortality (# tested).

	Deltamethrin						Lambdacyhalothrin		
	2009	2010	2011	2012	2013	2014	2009	2010	2011
Huambo		<i>100(59)*</i>	<i>94 (30)*</i>	94(16); <i>100(80)*</i>	<i>100(110)*</i>	100 (100)	<i>94(40)*</i>		
Huila		<i>100(20)*</i>	92 (15); <i>100(20)*</i>	94 (35)	94.7 (100)				
Cunene			93.3(15)	97.5 (80)					

	Bendiocarb					
	2009	2010	2011	2012	2013	2014
Huambo		<i>95(60)*</i>	<i>97 (24)*</i>	<i>100(20)*</i>	<i>100(89)*</i>	100 (100)
Huila			90 (30)	<i>100(40)*</i>	100 (100)	

	Fenitrothion		
	2012	2013	2014
Huambo	<i>100 (60)*</i>	<i>100 (50)*</i>	100 (100)
Huila		100 (100)	

PMI Insecticide Susceptibility Summaries

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 Oueme region (4 communes) with carbamates. In 2011, IRS was discontinued in Oueme and initiated in Atacora (7 communes, increased to 9 in 2012). For 2011-12, carbamates were used for IRS, and in 2013 IRS was shifted to carbamate in 4 districts and organophosphate in 5 districts. For 2014, 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.
- Organophosphates have been tested in Atacora, and *An. gambiae* s.l. still shows full susceptibility.

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Atacora Region: Pyrethroids and DDT. For *kdr* frequencies, unbolded numbers are data from 2011, **bold** numbers are **2012**. Pyrethroids and DDT are not used for IRS, and have not been tested since 2012.

sites	kdr freq	Deltamethrin .05%			Permethrin .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	0.71	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: Carbamate and organophosphates. For *ace-1* frequency, unbolded indicates 2011 frequency, **bold** indicates **2012** frequency. 2010-2012 indicates the most recent data point from that time period.

site	ace-1 freq	Bendiocarb .1 %			Propoxur .1%		Fenitrothion 1%			Pirimiphos methyl .25%		
		2010-2012	2013	2014	2012	2014	2012	2013	2014	2012	2013	2014
Pehunco	0.03	79 (101)		80 (116)	80 (64)	77 (79)	90 (89)		92 (101)	99 (89)		99 (103)
Kouande	0.08	79 (90)	80 (99)		90 (60)		88 (82)			100 (81)		
Materi	0.03	59 (73)			89 (70)		95 (96)			100 (72)		
Tanguieta	0.02	63 (106)	72 (115)		88 (59)		84 (49)	83.5 (97)		100 (90)	100 (89)	
Natintingou	0	62 (84)	66 (73)		91 (62)		95 (70)	87 (67)		100 (58)	99 (88)	
Copargo	0.03	90 (69)								100 (79)		

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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 2 rounds of spraying. *Kdr* and *ace-1* gene frequencies are from 2011.

site	kdr mutation	Deltamethrin .05%			Permethrin .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 .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 .05% 2014	Permethrin .75% 2014	DDT 4% 2014	Bendiocarb .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, 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.

COMMENTS ON DATA:

Data from 2012 were collected by RTI International, total number of mosquitoes tested was not reported. Data from 2013-2014 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 6 provinces.
- There is widespread resistance to DDT and permethrin, but only low levels of resistance against deltamethrin.
- There is full susceptibility to carbamates and organophosphates.

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Pyrethroids and DDT:

Province	District	Site	Deltamethrin			Permethrin		Lambda-cyhalothrin	DDT		
			2012	2013	2014	2012	2013	2012	2012	2013	2014
Eastern Kasai	Lodja	Lodja	100	96 (100)	98 (100)	64	49 (100)	100	40		13 (100)
Eastern Kasai		Mbujimayi	100			28		100	46		
Western Kasai	Kananga	Tshikaji	85	92 (100)	98 (100)	56	45 (100)	100	50		13 (100)
Western Kasai	Kananga	Mikalayi			99 (100)						42 (100)
Haut Congo	Kisangani	Kabondo		100 (100)	99 (100)		27 (100)		54	40 (100)	17 (100)
Katanga	Kapolowe	Kapolowe	85	95 (25)	99 (80)	66	39 (25)	100			45 (80)
Kinshasa	Tshangu	Kingasani			99 (100)						17 (100)
South Kivu		Katana	96			100		97			

Carbamates and Organophosphates:

Province	District	Site	Bendiocarb			Malathion	Fenitrothion	Pirimiphos methyl
			2012	2013	2014	2012	2013	2014
Eastern Kasai	Lodja	Lodja	100	100 (100)	100 (100)	100	100 (100)	100 (100)
Eastern Kasai		Mbujimayi	100			100		
Western Kasai	Kananga	Tshikaji	100	100 (100)	100 (100)	100	100 (100)	100 (100)
Western Kasai	Kananga	Mikalayi			100 (100)			100 (100)
Haut Congo	Kisangani	Kabondo		100 (100)	100 (100)		100 (100)	100 (100)
Katanga	Kapolowe	Kapolowe	100	100 (25)	100 (80)	100	100 (25)	100 (80)
Kinshasa	Tshangu	Kingasani			100 (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 2012-2014, 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.

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. CDC bottle bioassays showed resistance to pirimiphos-methyl, but may have been conducted incorrectly; WHO assays show 100% susceptibility.

CONCLUSIONS:

- There is high pyrethroid and DDT resistance in all tested sites, with varying intensity of resistance.
- There is carbamate resistance in Omanada, Bahirdar, and Humbo, with emerging resistance in Tigray and Gambela. Propoxur appears to have slightly better efficacy than 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 pyrethroids and DDT, *An. gambiae* s.l., 2012-2014

WHO tube assays				Deltamethrin			Permethrin			Lambdacyhalothrin			Etofenprox			Alpha cypermethrin			DDT		
Region	Zone	District	Site	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
Oromia	East	Gida	Gutin	42																	
	Wollega	Ayana		(200)																	
Oromia	West	Nejo Town		61																	
	Wollega			(100)																	
Oromia	Kelem	Dale Sedi	Aweitu-Gendosa	52																	
	Welega			(100)																	
Oromia	East	Gobu	Gambella	16																	
	Wollega	Sayo	Tere	(100)																	
Oromia	West	llu Gelan	Siba Biche	11																	
	Shoa			(100)																	
Oromia	Jimma	Oma	Asendabo	11	26	42	11	22	16	26	15	39	9		55	25		35	4	9	7 (88)
		Nada		(215)	(100)	(100)	(100)	(100)	(100)	(105)	(100)	(100)	(115)		(100)	(105)		(100)	(103)	(100)	
SNNPR	Halaba	Halaba	Halaba Town	1															0		
				(100)															(100)		
Oromia	Arsi	Zeway-Dugda	Shenen	27	36	11			3			4		20	29		32	5	13	26	6 (97)
				(100)	(100)	(196)			(101)			(94)		(100)	(101)		(100)	(100)	(100)	(100)	
Oromia	Illubabor	Chewaka	Chewaka	12	51	46			31	44	11				24			32	3	22	6
				(100)	(100)	(97)			(80)	(100)	(97)				(95)			(96)	(100)	(100)	(100)
Amhara	Bahirdar	Bahirdar	Zenzlima-Robit	44	20	25			66		24	23	55	23	50	43	61	6	16	9	9 (75)
				(100)	(100)	(75)			(100)		(100)	(112)	(75)	(71)	(120)	(75)	(100)	(100)	(100)	(100)	
Oromia		Ameya			16			12		9										2	
					(100)			(100)		(100)										(100)	
Oromia		Wonchi			23			19		18										4	
					(100)			(94)		(100)										(100)	
Oromia		Humbo	Abaya		13					13			33			24				8	
					(74)					(100)			(100)			(100)				(100)	
Tigray		Alamata				44			10			58			19			77			25
						(100)			(100)			(100)			(100)			(100)			(100)
Afar		Amibara				45			19			46			87			73			19
						(99)			(94)			(92)			(100)			(103)			(101)
Gambela		Gambela				18			28			15			11			15			13
						(83)			(88)			(88)			(88)			(88)			(88)

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WHO tube assay for carbamates and organophosphates, *An. gambiae* s.l., 2012-2014

Region	Zone	District	Site	Bendiocarb			Propoxur			Fenitrothion			Malathion			Pirimiphos methyl		
				2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
Oromia	East	Gida	Gutin				100											
	Wollega	Ayana					(100)											
Oromia	West	Nejo Town					100											
	Wollega						(100)											
Oromia	Kelem	Dale	Aweitu-				100			98								
	Welega	Sedi	Gendosa				(100)			(100)								
Oromia	East	Gobu	Gambella	100			100			100								
	Wollega	Sayo	Tere	(75)			(100)			(100)								
Oromia	West	Ilu Gelan	Siba	97			98			100								
	Shoa		Biche	(150)			(100)			(100)								
Oromia	Jimma	Oma	Asendabo	94	92	86	99(205)	98	100	99	97	100	66	81	73	100	100	100
		Nada		(205)	(100)	(88)		(100)	(100)	(105)	(100)	(100)	(115)	(100)	(100)	(105)	(100)	(100)
SNNPR	Halaba	Halaba	Halaba	98			99			100			48					
			Town	(100)			(100)			(100)			(100)					
Oromia	Arsi	Zeway-	Shenen	100	100	100	100	100	100	99		100	90	90	93		100	100
		Dugda		(100)	(100)	(101)	(100)	(100)	(101)	(100)		(106)	(100)	(100)	(98)		(100)	(103)
Oromia	Illubabor	Chewaka	Chewaka	90	100	100	96	100	100	100	100	100	58	71	94		100	100
				(100)	(100)	(100)	(100)	(100)	(100)	(100)	(102)	(100)	(100)	(100)	(93)		(100)	(100)
Amhara	Bahirdar	Bahirdar	Zenzlima-	87	75	87	100	96	99	100	100	100	26	33	89	100	100	100
			Robit	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(75)	(100)	(75)	(75)	(100)	(100)	(75)
Oromia		Ameya			100			100			100			60			100	
					(100)			(100)			(100)			(100)			(100)	
Oromia		Wonchi			100			100			100			88			100	
					(100)			(100)			(98)			(100)			(98)	
Oromia		Humbo	Abaya		75			75			100			96			100	
					(275)			(175)			(100)			(100)			(75)	
Tigray		Alamata				96			98			100			89			100
						(100)			(100)			(100)			(100)			(100)
Afar		Amibara				100			100			100			100			100
						(105)			(102)			(102)			(101)			(99)
Gambela		Gambela				92			100			100			96			100
						(88)			(88)			(88)			(88)			(100)

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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, and in 2013, PMI scaled down to 4 districts (Savelugu/Nanton, East Mamprusi, West Mamprusi, and Bunkpurugu/Yunyoo). In 2013 and 2014, organophosphates were used for IRS.

COMMENTS ON DATA:

Susceptibility data was collected in collaboration with Noguchi Memorial Institute for Medical Research.

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.

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.
- There is full susceptibility to organophosphates, with the exception of possible resistance to fenithrothion in Tolon/Kumbungu. There is 100% susceptibility to pirimiphos-methyl.

PMI Insecticide Susceptibility Summaries

WHO tube assays for pyrethroids and DDT, on *An. gambiae* s.l., 2013-2014. District abbreviations: T/K (Tolon/Kumbungu), S/N (Savelugu/Nanton), B/Y (Bunkpurugu/Yunyoo), T (Tamale).

District	Site	Alpacypermethrin .4%		Deltamethrin .05%		Permethrin .75%	Etofenprox 0.5%	DDT 4%	
		2013	2014	2012	2013	2014	2014	2013	2014
T/K	Gbullung	34 (100)	91 (100)		24 (100)		97 (75)	21 (100)	11 (100)
T/K	Woribugu	53 (100)	57 (100)						15 (100)
S/N	Nanton	54 (100)	52 (100)		69(100)			19 (100)	
S/N	Tarikpaa	24 (100)	92 (100)		75(100)	56 (100)	33 (100)	16 (100)	18 (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)			36 (100)			9 (100)

WHO tube assays for carbamates and organophosphates, on *An. gambiae* s.l., 2013-2014. District abbreviations: T/K (Tolon/Kumbungu), S/N (Savelugu/Nanton), B/Y (Bunkpurugu/Yunyoo), T (Tamale).

District	Site	Propoxur .1%	Bendiocarb .1%		Fenitrothion 1%	Malathion 5%	Pirimiphos-methyl 0.25%	
		2013	2013	2014	2013	2013	2013	2014
T/K	Gbullung	91 (100)	77 (100)	96 (100)	98 (100)	100 (100)	100 (100)	99 (100)
T/K	Woribugu		74 (100)		96 (80)	100 (100)	100 (100)	100 (100)
S/N	Nanton	96 (100)	99 (100)	96 (100)	100 (100)		100 (100)	99 (100)
S/N	Tarikpaa	81 (100)	90 (100)	94 (100)	99 (100)		100 (100)	100 (100)
B/Y	Yunyoo				100 (100)		100 (100)	98 (100)
B/Y	Bunbuna		91 (100)	99 (100)	100 (100)		100 (100)	99 (100)
B/Y	Sambiruk	95(100)	96 (100)		99 (100)		100 (100)	
Tamale	Tugu	90 (100)		88 (100)	100 (100)		100 (100)	100 (100)
Tamale	Yong						98 (100)	
Tamale	Kulaa			83 (100)				99 (100)

PMI Insecticide Susceptibility Summaries

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	
fenithrothion		97	95	100
malathion	100	96	98	95

PMI Insecticide Susceptibility Summaries

GUINEA

PMI supports collection of entomological in 4 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 is underway.

Corrected mortality (and number tested) of *Anopheles gambiae s.l.* tested in WHO susceptibility tests in three sites in Guinea

Site	Deltamethrin 0.05%	Permethrin 0.75%	Alpha- cypermethrin 0.1%	Lambda- cyhalothrin 0.05%	DDT 4%	Bendiocarb 0.1%
Boke	86 (45)	88 (42)			44 (45)	100 (45)
Kissidougou	100 (42)	18 (40)	58 (40)	61 (43)	28 (44)	87 (40)
Faranah	100 (75)	43 (75)			31 (75)	100 (75)

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.
- Resistance to bendiocarb was noted in Kissidougou, but not in the other sites tested.

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.

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.

2012-2013 – WHO tube bioassays were used. Numbers were not reported in 2013.

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)
- 2012-2013 data shows that *An. gambiae* s.l. is 100% susceptible to bendiocarb, where tested. However, 2009-2011 data shows resistance to bendiocarb for *An. gambiae* s.l. in Bungoma, Busia, and Kakamega. Bungoma and Kakamega weren't re-tested after 2011.
- *An. gambiae* s.l. is fully susceptible to OPs in areas where it has been tested (Kisumu, Homa Bay, Migori)
- *An. funestus* has only been tested with pyrethroids, and shows high resistance where tested; this species has not been tested with carbamates or OPs.

PMI Insecticide Susceptibility Summaries

2012/13 WHO tube assay data for *An. gambiae* s.l.

County	Location	Deltamethrin		Permethrin		Bendiocarb		Malathion	
		2012	2013	2012	2013	2012	2013	2012	2013
Kisumu	Nyando	71 (98)	84	41 (99)	96	100 (100)	100	100 (100)	100
	Muhoroni	78 (100)		80 (100)					
	Nyakach			89 (99)					
Homa Bay	Marindi	74 (168)		52 (46)					
	Ndhiwa	39 (116)		75 (89)					
	Rachuonyo	80 (538)	96	85 (122)	92		100	98 (60)	100
	Homa Bay		60		71				
Migori	Nyatike	73 (187)		64 (97)				100 (35)	
	Rongo	60 (53)		71 (49)					
	Karungu		70		55		100		100
Bungoma	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		66				

2013 *An. funestus* WHO tube assay results

County	Sub-County	deltamethrin
Siaya	Bondo	75
Kisumu	Nyando	59
Busia	Teso	20

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.

Species	Location	Permethrin	Deltamethrin	Alpha-cypermethrin	Lambda-cyhalothrin	DDT	Bendiocarb	Malathion
		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.

CONCLUSIONS:

- There are high levels of resistance to pyrethroids and DDT in all locations tested.
- For organophosphates, there is potential emerging resistance to fenithrothion, but not pirimiphos-methyl.
- There is full susceptibility to carbamates in Montserrado and Grand Gedeh counties, but probable resistance in Bong County (2013-2014) and Grand Bassa (historical data).

PMI Insecticide Susceptibility Summaries

WHO tube assay results for *An. gambiae* s.l.: DDT and pyrethroids, 2012-2014

Region	Site	deltamethrin			alphacypermethrin		DDT	
		2012	2013	2014	2012	2013	2013	2014
Montserrado	Montserrado	47 (153)			53 (100)			
Bong	Monrovia			46 (100)				27 (100)
	SKT			15 (128)				27 (100)
	Suakoko		15 (128)			23 (100)	27 (100)	
Margibi	Fuamah		34 (102)					
	Kpaai	52 (101)						
	Jorkole	59 (68)						
Grand Gedeh	Mamba kaba	84 (100)			81 (220)			
	Margibi	29 (160)						
Grand Bassa	Zwedru			62 (100)				30 (100)
Cape Mount	Bokay Town	12 (25)		78 (100)				54 (100)
	Nimba Point			36 (100)				16 (100)

WHO tube assay results, *An. gambiae* s.l.: carbamates and organophosphates, 2012-2014

Region	Site	bendiocarb			fenithrothion			pirimiphos-methyl	
		2012	2013	2014	2012	2013	2014	2012	2013
Montserrado	Monrovia			99 (100)			95 (100)		
Bong	SKT			95 (100)			100 (102)		
	Suakoko		95 (100)			100 (102)			100 (100)
Margibi	Kpaai				94 (143)			100 (81)	
	Margibi	100 (44)			98 (40)			100 (91)	
Grand Gedeh	Zwedru			98 (100)			100 (100)		
Grand Bassa	Bokay Town						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 .05%	Lambda- cyhalothrin	Bendiocarb .1%	DDT 4%	Fenithrothion
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)		

PMI Insecticide Susceptibility Summaries

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.

COMMENTS ON DATA:

Resistance monitoring in Madagascar is carried out by the National Malaria Control Program (PNLP), the GF7/UGP, OMS/Gates Foundation, the Institute Pasteur Madagascar (IPM), NSA-PACT-UN, and PMI (via Abt Associates, and RTI).

2006-2014: 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.
- For *An. gambiae* s.l., there is emerging resistance to pyrethroids at 9 sites, with confirmed resistance in an additional 9 sites: Ankazobe, Antsirabe 2, Betafo, Boriziny, Brickaville, Fianar 2, Marovoay, and Morondava.
- 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.
- 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. 2006-2011 indicates the most recent data point from that period.

District	Deltamethrin				Lambdacyhalothrin				Permethrin				Alphacypermethrin		
	2006-2011	2012	2013	2014	2006-2011	2012	2013	2014	2006-2011	2012	2013	2014	2012	2013	2014
AMBANJA		100 (80)													
AMBILOBE		100 (100)	100 (100)			100 (100)	100 (100)		100 (80)	100 (100)*	100 (100)		100 (100)*		
AMBOASARY	100 (103)*	99(100)	100 (100)	100 (100)	95 (100)*	100 (102)	100 (100)	98 (100)	92 (100)*		99 (100)*	98 (100)	100 (101)*	100 (100)*	96 (100)*
AMBATOFINANDRAHANA	99 (100)*	100 (100)	100 (100)	100 (100)	97 (100)*	96 (100)	99 (100)	97 (100)	100 (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)*
AMBOSITRA				99 (100)				100 (100)				99 (100)			100 (100)*
AMPANIHY				98 (100)				99 (100)				98 (100)			95 (100)*
ANDILAMENA					96 (100)										
ANJOZOROBE	100(106)														
ANKAZOBE	100 (100)	100 (100)	100 (100)	98 (100)	99 (100)	100 (100)	100 (100)	96 (100)	100 (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)					
ATSIMONDRANO	91 (200)				97 (100)				100(97)						

PMI Insecticide Susceptibility Summaries

BEKILY		100 (200) *		98 (100)		100 (200)*		100 (100)		100 (200)*		99 (100)		100 (200)*		95 (100)*
BETAFO	100 (100)*	99(1 00)	100 (100)	100 (100)	100 (100)*	100 (100)	100 (100)	100 (100)	100 (100)*		82 (100)*	100 (100)		100 (100)*		97 (100)*
BETIOKY SUD	100 (96)															
BETROKA		100 (100)				100 (100)				100 (100)						
BORIZINY	75 (100)	87 (100)			80 (100)	83 (100)			68 (100)	82 (100)						
BRICKAVILLE		100 (100)	100 (100)			100 (100)	100 (100)		82 (100)	100 (100)*	84 (100)*		100 (100)*	100 (100)*		
FENOARIVO BE		100 (100)			100 (100)	97 (100)			100 (100)	98 (100)						
FIANAR II	92 (104)								63 (101)							
FORT DAUPHIN		100 (100)	100 (100)			100 (100)	100 (100)			99 (101)*	94 (100)		100 (100)*	95 (100)*		
IAKORA					100 (100)											
IHOSY	100 (20)				100 (15)				100 (20)							
MAHABO		100 (100)				99 (100)				98 (100)						
MANAKARA	100 (56)															
MANANDRIANA									95 (100)							
MAROVOAY	96 (100)				95 (100)				86 (100)							
MORONDAVA					53 (100)											
SAKARAHA	100 (100)				100 (100)				100 (100)							
SOAVINANDRIANA					96 (100)											
TSARATANANA	100 (100)	100 (100)			91 (100)	97 (100)			100 (100)	100 (100)*			97 (100)*			
TSI/DIDY	100 (145)															
VANGAINDRANO	100 (67)															

PMI Insecticide Susceptibility Summaries

An. gambiae s.l. WHO tube and CDC bottle bioassay results: DDT, carbamates, and organophosphates. *Purple italics* ^ indicates malathion was used in place of fenitrothion for testing.

District	DDT				Bendiocarb				Propoxur	Fenitrothion			Pirimiphos-methyl
	2006-2011	2012	2013	2014	2006-2011	2012	2013	2014	2012	2006-2011	2012	2013	2014
AMBATO-BOENI	100 (106)												
AMBANJA		100 (80)											
AMBILOBE		100 (100)	100 (100)		100 (80)	100 (100)	100 (100)				100 (100)	100 (100)	
AMBOASARY	91 (100)	98 (100)	98 (100)	97 (100)	100 (101)*	100 (103)	100 (100)	100 (100)		100 (102)	100 (100)	100 (100)	
AMBATOFINANDRAHANA	89 (122)	97 (100)	87 (100)	97 (100)	100 (100)*	100 (100)	98 (100)	100 (100)		<i>100 (120)^</i>	97 (100)	100 (100)	100 (100)
AMBOHIDRATRIMO						86 (100)							
AMBOVOMBE		100 (100)*				100 (200)*					99 (200)*		100 (100)
AMBOHIMAHASOA				85 (100)				100 (100)					100 (100)
AMBOSITRA				98 (100)				98 (100)					100 (100)
AMPANIHY				93 (100)				100 (100)					100 (100)
ANDILAMENA	100 (100)												
ANJOZOROBE										<i>100 (111)^</i>			
ANKAZOBE	97 (68)	48 (100)	72 (100)	77 (100)	96 (100)*	100 (100)	100 (100)	100 (100)		100 (57)	100 (100)	100 (100)	100 (100)
ANTOETRA (in Ambositra district)			95 (100)				99 (100)					100 (100)	
ANTSIRABE 2									100 (100)		100 (100)		
ATSIMONDRANO	88 (100)				84 (200)					97 (100)			
BEKILY		99 (200)*		100 (100)		100 (200)*		98 (100)			94 (200)*		100 (100)

PMI Insecticide Susceptibility Summaries

BETAFO	91 (199)	68 (104)	36 (100)	86 (100)	100 (100)*	100 (100)	100 (100)	100 (100)		98 (103)	100 (100)	100 (100)	100 (100)
BETIOKY SUD	97 (73)												
BETROKA								100 (100)					
BORIZINY		93 (100)				94 (100)					99 (100)		
BRICKAVILLE			97 (100)		94 (100)	100 (101)	100 (100)				100 (101)	100 (100)	
FENOARIVO BE	87 (100)				96 (100)			100 (100)		100 (100)			
FIANAR II	72 (106)									100 (103)^			
FORT DAUPHIN		92 (100)	90 (100)			100 (100)	100 (100)				100 (100)	100 (100)	
IAKORA										100 (100)			
IHOSY	100 (32)				100 (20)								
MAEVATANANA	93 (100)				100 (100)					100 (100)			
MAHABO	94 (100)				98 (100)			100 (100)		100 (100)			
MAMPIKONY	100 (70)												
MANAKARA	65 (100)												
MANANDRIANA	92 (100)												
MAROVOAY					87 (100)								
MIDONGY ATSIMO	100 (100)									100 (100)			
MORONDAVA	89 (47)				100 (77)								
SAKARAH	98 (100)				100 (100)					100 (100)			
SOANIERANA IVONGO	91 (100)												
TSARATANANA	99 (100)				95 (100)	100 (100)				98 (100)	95 (100)		
TSI/DIDY	100 (40)												
TULEAR II	100 (118)												

PMI Insecticide Susceptibility Summaries

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

Site	Deltamethrin		Permethrin 2012	Lambdacyhalothrin		DDT			Bendiocarb		Fenitrothion		Propoxur 2012
	2009	2012		2010	2012	2006-08	2010	2012	2006-08	2012	2010	2012	
AMBATO BOENI				100 (80)		100 (80)		100 (60)		100 (60)	100 (80)		
AMBILOBE				100 (80)									
ANJOZOROBE						98 (111)							
ANKAZOBE									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 Nkhotakota 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 Nkhotakota and Salima was funded by PMI and sprayed with organophosphate, while IRS in the remaining districts was funded by the Malawi government and sprayed with pyrethroids. In 2012 PMI only sprayed Nkhotakota, again with organophosphate. PMI-supported IRS was suspended in 2013, but the government has continued some spraying with pyrethroids.

COMMENTS ON DATA:

Susceptibility data was collected in collaboration with the Malaria Alert Center (MAC). F1 progeny of wild caught adults were used for testing in WHO tube assays. For 2014, sample sizes were not reported, and some data was estimated from bar graphs, as raw numbers were not provided (accurate to within 2-3 percentage points). 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 Nkhotakota district." (mortality without PBO = 17% and 15%, and 3% and 2%, respectively)

CONCLUSIONS:

- *An. funestus* in Malawi shows strong resistance to both pyrethroids and carbamates and probable resistance to 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. 2009-2012 data represents the most recent data point within that time period. In 2013, limited mosquito numbers prevented extensive insecticide resistance assays.

District	Deltamethrin .05%		Permethrin .75%		Lambdacyhalothrin .05%	DDT 4%	
	2010-12	2014	2009-2012	2014	2010-12	2010-12	2014
Mangochi	74 (116)		79 (191)		70 (98)		
Chikwawa	39 (199)	15	78 (201)	17	66 (276)	93 (278)	100
Salima	58.5 (254)	21	69 (175)	20	32 (190)	90 (100)	
Nkhotakota	46 (414)	2	73 (301)	3	36 (294)	99 (102)	
Karonga							
Nkhata Bay	21 (100)	10	80 (200)	50	30 (200)	97 (184)	
Machinga	44 (336)		70 (209)				
Dedza	54 (461)		81 (124)		36 (100)		
Likoma	41 (174)		40 (146)			100 (155)	
Phalombe				57			

An. funestus, carbamate and organophosphate WHO tube assays. 2009-2012 data represents the most recent data point within that time period.

District	Bendiocarb .1%		Propoxur .1%	Malathion 5%		Pirimiphos-methyl	
	2010-12	2014	2010-2012	2010-12	2014	2010-12	2014
Mangochi	99 (100)			100 (100)			
Chikwawa	64 (256)	5	83 (124)	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)		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. 2009-2012 data represents the most recent data point within that time period.

District	Deltamethrin .05%		Permethrin .75%		Lambda-cyhalothrin .05%	Bendiocarb .1%		Malathion 5%
	2010-11	2014	2009-11	2014	2010-11	2010-12	2014	2010-11
Chikwawa	100 (110)	90	82 (81)		96 (81)	100 (100)		100 (23)
Salima	65 (21)		99 (125)			100 (100)		
Nkhotakota			89 (27)					
Karonga	100 (590)	57	98 (374)	37	100 (86)		55	
Nkhata Bay			90.5 (95)			100 (50)		
Machinga	87.5 (8)							
Nsanje			88 (113)					
Blantyre					100 (25)			
Phalombe				70				

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.

COMMENTS ON DATA:

Susceptibility data was collected in collaboration with Malaria Research & Training Center (MRTC), 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.

CDC bottle bioassays show high pyrethroid resistance intensity:

Site	Mortality @ 10X permethrin	Mortality @ 10X deltamethrin
Koulikoro	22%	57%
Baraoueli	86%	100%
Bla	73%	91%

CONCLUSIONS:

- In *An. gambiae* s.l., there is probable or confirmed resistance to pyrethroids and DDT in all districts, often with high resistance frequency.
- Pyrethroid and DDT resistance is due to a combination of high *kdr* frequency and metabolic resistance.
- *An. gambiae* s.l. is susceptible to carbamates and organophosphates in IRS districts. However, in some non-IRS districts, there is confirmed resistance to carbamates and probable resistance to fenitrothion.

PMI Insecticide Susceptibility Summaries

WHO tube bioassay results (2009-2013) for *An. gambiae* s.l., pyrethroids and DDT. 2009-2012 indicates the most recent data point for that site.

Site	Deltamethrin .05%			Permethrin .75%		Lambda-cyhalothrin .05%		DDT 4%		
	2009-12	2013	2014	2009-10	2014	2009-12	2013	2009-12	2013	2014
Koulikoro	50 (300)	98 (104)	15 (104)		6 (102)	13 (98)	13 (100)	11 (95)	10 (99)	4 (104)
Bla	68.5 (400)	38 (103)	14 (98)		47 (100)	58 (102)	77 (103)	48 (99)	52 (104)	6 (101)
Baraoueli	61 (300)	50 (101)	31 (100)	79 (300)	25 (102)	33 (100)	45 (103)	13 (93)	35 (104)	16 (90)
Bamako	80 (100)			75 (100)		7		18		
Kati	97 (200)			68 (200)		12		17		
Gao	94 (100)			69 (100)		74 (100)		95 (100)		
Niono	91 (200)			97 (200)		33		44		
Badiangara	79			79.5 (200)		66.5 (200)		76		
Bougouni	91			98.5 (200)		87.5 (200)		28		
Kita	88 (200)			98 (200)		74		75		
Djenné	16			100 (100)		94 (100)		42		
Tombouctou	97 (100)			98 (100)		100 (100)		52 (100)		
Bankass	32							47		
Kadiolo						37		12		
Yanfoila						50		23		

WHO tube bioassay results (2009-2013) for *An. gambiae* s.l., carbamates and organophosphates. 2009-2012 or 2009-2010 indicates the most recent data point for that site.

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

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, Nicosadala, Namacurra, Mocuba, Morrumbala, Milange, Maganja da Costa, and Mopeia. In 2014, 5 districts were sprayed: Mocuba, Milange, Morrumbala, Quelimane, and Mopeia. Pyrethroids were still used for IRS in 2014.

COMMENTS ON DATA:

All districts evaluated are in Zambezia Province³

2007-2008 collections: Mosquitoes tested were field-collected adults. Of 2011 targeted districts, 6 unique villages were evaluated. One was tested using *An. gambiae* s.l. (Maganja da Costa) and 6 used *An. funestus* (Maganja da Costa, Mocuba, Morrumbala, Namacurra, Nicosadala, and Quelimane)

2009/10 collections: Blood fed females were collected in the field and induced to lay eggs. Testing was done on F1 offspring. Data were collected from three 3 unique districts. Two districts were evaluated for *An. gambiae* s.l. (Muibi & Mocuba). For *An. funestus*, the districts evaluated were Mugeba & Milange.

2010 collections: *An. gambiae* s.l. reared from field-collected larvae were used. Data were collected from three 3 unique districts. However, of the 2011-targeted districts, only 2 were evaluated (Maganja da Costa & Mopeia). The other district evaluated was Pebane.

2011 collections: *An. gambiae* s.l. reared from field-collected larvae were used. Data were collected from 2 districts, both of which were 2011 target districts (Maganja da Costa & Mocuba).

2012 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 Nicosadala).

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).

CONCLUSIONS:

- While the low number of mosquitoes routinely being tested is a concern, the general insecticide resistance trends indicate susceptibility for *An. gambiae* s.l. to pyrethroids in most areas. There is probable resistance to pyrethroids in Mocuba and Morrumbala. *An. gambiae* s.l. is susceptible to DDT, carbamate, and organophosphate in all tested areas.
- *An. funestus* is beginning to show low to moderate pyrethroid resistance in several districts.
- Early data shows probable *An. funestus* carbamate resistance in Mugeba and Milange, but this has not been tested since 2010. *An. funestus* also shows probable resistance to organophosphates in Mocuba.

³ Some data taken from Abilio 2011, *Malar J*

PMI Insecticide Susceptibility Summaries

WHO tube assays for Zambezia Province, *An. gambiae* s.l., 2007-2014. 2007-2012 indicates the most recent data point from that time period.

	Deltamethrin .05%			Lambdacyhalothrin .05%			DDT 4%			Bendiocarb .1%			Fenitrothion 1%		
	2007-2012	2013	2014	2007-2012	2013	2014	2007-2011	2013	2014	2007-2011	2013	2014	2007-2011	2013	2014
Maganja da Costa	100 (20)			100 (62)			100 (22)			100 (43)			100 (20)		
Mocuba	100 (80)		100 (100)	90 (40)		100 (100)	100 (73)		100 (100)	100 (46)		100 (100)	100 (45)		100 (100)
Muibi				100 (14)			100 (29)								
Mopeia				100 (41)			100 (20)			100 (21)					
Pebane				100 (57)			100 (20)			100 (45)					
Morrumbala	100 (40)	97 (100)			95 (100)			98 (100)			100 (100)			100 (100)	
Nicoadala	100 (100)	100 (100)									100 (100)				

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

District	Deltamethrin .05%			Lambdacyhalothrin .05%			Bendiocarb .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 .025% Deltamethrin

^{*} Test conducted with Permethrin .75%

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 the University of Jos.

2011: CDC bottle assays were used for *An. gambiae* s.l. susceptibility testing. Tests were performed on field-collected larvae from Nasarawa Eggon. Four replicates and one control were run for each insecticide with 25 mosquitoes per bottle. Knockdown times showed that *An. gambiae* s.l. was susceptible to bendiocarb, lambdacyhalothrin, malathion, alphacypermethrin, fenitrothion, deltamethrin, and permethrin; *An. gambiae* s.l. was resistant to pirimiphos-methyl, DDT, and ETAA.

2012: CDC bottle bioassays and WHO tube assays were conducted in Nassarawa Eggon. 100 mosquitoes were used for each method. The test methods show slight disagreement for pyrethroids, but generally show probable resistance. Both tests show 100% susceptibility to carbamates and OPs.

2013-2014: *An. gambiae* s.l. was tested with both WHO tube bioassays and CDC bottle bioassays, with roughly similar results. Major differences between test methods were seen for:

lambdacyhalothrin showed higher survival in CDC bottle bioassays

pirimiphos-methyl showed lower survival in CDC bottle bioassays

alphacypermethrin WHO v. CDC: 70% v. 93% (Rivers 2014); 99% v. 66% (Nasarawa 2014); 100% v. 69% (Nasarawa 2013)

deltamethrin WHO v. CDC: 76% v. 90% (Rivers 2014); 83% v. 58% (Nasarawa 2014)

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.

PBO synergist results: The difference in 24-hour exposure mortality between the synergized and unsynergized samples, exposed to either deltamethrin or DDT, was not significant (Epe: DDT, $p=0.49$, deltamethrin, $p=0.52$); Nasarawa Eggon: DDT, $p=0.52$, deltamethrin, $p=0.55$). There was no significant reduction in mortality of samples synergized prior to exposure to DDT or deltamethrin.

CONCLUSIONS:

- There are high levels of pyrethroid and DDT resistance in all areas (with the exception of deltamethrin and alphacypermethrin in Nassarawa, which shows differing results between years and between WHO and CDC bioassays). Molecular & synergist assays indicate that pyrethroid and DDT resistance is mediated by *kdr* target site resistance.
- Other than Lagos, all populations show high resistance to pirimiphos-methyl.
- All populations remain susceptible to carbamates (bendiocarb and propoxur), and fenitrothion.

PMI Insecticide Susceptibility Summaries

WHO tube assays for *An. gambiae* s.l., 2013-2014

Region	Permethrin	Deltamethrin		Alphacypermethrin		Lambdacyhalothrin		DDT		Bendiocarb		Propoxur	Fenitrothion	Pirimiphosmethyl
	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2014	2013	2014
Plateau	95 (92)		96.8 (94)		100 (89)		84 (95)		63 (95)		100 (90)	99 (90)		71 (84)
Jigawa	50 (100)		68.6 (86)		87 (76)		63 (88)		41 (78)		100 (70)	99 (93)		62 (95)
Rivers	73 (75)		76 (75)		70 (60)		75 (75)		63 (60)		100 (75)	100 (75)		65 (75)
Enugu	30 (80)		84 (80)		66 (80)		50 (80)		31 (80)		100 (80)	100 (80)		66 (80)
Nassarawa	81 (80)	33	97.5 (80)	100	99 (80)	28	32 (80)	9	9 (80)	100	100 (80)	100 (80)	100	46 (80)
Lagos	77 (100)		92 (100)		93 (100)		69 (100)		17 (100)		100 (100)			98 (100)
Doma		44		80		37		9		100			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.

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.

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.

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.
- There is probable *An. gambiae* s.l. resistance to carbamates in Nyagatare and Bugesera; 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.

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.

district	site	Deltamethrin			Lambdacyhalothrin			Permethrin		Etofenprox 2013	DDT		
		2011	2012	2013	2011	2012	2013	2011	2013		2011	2012	2013
Nyagatare	Nyagatare			82			74		76	76			99
	Mimuli	98	23	81	100	20	57	86	66	82	76	84	95
Bugesera	Mwogo			88			85		90	80			99
	Rilima			99			95		98	97			100
	Mareba	99	90	90	100	86	86	99		95	99	97	97
Gisagara	Kirarambogo			58			35		50	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
Rutsisro	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.

district	site	Bendiocarb			Fenithrothion		
		2011	2012	2013	2011	2012	2013
Nyagatare	Nyagatare			100			100
	Mimuli	94	84	100	100	100	100
Bugesera	Mwogo			93			100
	Rilima			97			100
Gisagara	Mareba	100	100	100	100	100	100
	Kirarambogo			100			100
	Gakoma			99			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

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 Hodar, Kougheul, Koumpentoum and Vélingara

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 in 2014.

COMMENTS ON DATA:

Susceptibility testing for 2008-2010 was financed by Gates/WHO. All tests were conducted by Cheikh Anta Diop University (UCAD).

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. pharoensis*, *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.
- Resistance to carbamates has been seen in several regions (Dakar, Kanel, and Thies). There is also probable resistance in Kaolack, Kedougou, and Kolda. There are several sites where bendiocarb resistance was previously reported, but recent tests show full susceptibility.
- There is full susceptibility to organophosphates in all areas, with the exception of probable resistance to fenitrothion in Kedougou, Kolda, and Tambacounda districts. There is 99-100% susceptibility to malathion and pirimiphos-methyl in all sites.

PMI Insecticide Susceptibility Summaries

An. gambiae s.l., WHO tube assays for pyrethroids, (2008-12 shows the most recent data available between 2008 and 2012)

District	Region	Deltamethrin			Lambdacyhalothrin			Permethrin			Alphacypermethrin	
		2008-12	2013	2014	2008-12	2013	2014	2008-12	2013	2014	2013	2014
Dakar Centre	Dakar	71		89.4	30		85.8	33		75.7		85.8
Guediawaye	Dakar	79		43.4	60		38.7	23		5		69.4
Pikine	Dakar			50			59.3			23.3		
Bambey	Diourbel			87.1					98 (102)	77.7		
Dioffior	Fatick	80			81			81				
Fatick	Fatick								100 (105)	99.1		
Niakar	Fatick		100 (107)						100			
Kaffrine	Kaffrine		88 (102)	98		67 (99)	64		91	91	73 (106)	84.8
Koungheul	Kaffrine	98 (91)	100 (83)	100	94 (94)		84.9	91 (97)	96 (84)	96.5	88 (81)	96
Maleme Hodar	Kaffrine	90 (93)	78 (108)	85	71 (96)	55 (100)	71	69 (100)	89 (103)	82	93 (96)	84.7
Guinguineo	Kaolack	92 (106)			75 (102)			70 (99)	70 (102)		70 (98)	
Ndoffane	Kaolack		88 (103)	81.9		89 (103)	70.1		59 (98)	45.3	90 (106)	
Nioro	Kaolack	88 (91)	98 (102)	80.1	88 (94)	97 (110)	76.4	91 (98)	70 (90)	46.2	93 (101)	
Kedougou	Kedougou	16		72	7		64.1	12		45		53.9
Kolda	Kolda			49						60		67.8
Velingara	Kolda	95 (101)		86.5	89 (106)			96 (98)	74 (76)		94 (53)	
Barkédji	Louga	93		87.8	78			86		100		
Linguère	Louga	100			98			91				
Gabou (Bakel)	Matam			92								
Kanel	Matam			98.8								
Ranerou	Matam			96.2								
Podor	St. Louis	83			73			66				
Richard Toll	St. Louis		88.3	91.4		71.7	97.2	18 (144)	79.4	78.2	94 (105)	94.7
Koumpentoum	Tambacounda	95 (93)		83	63 (100)		75.2	96 (97)	100 (76)	80.4	83 (77)	84.1
Tambacounda	Tambacounda	71		68	88		36	41		50		82
Mbour	Thies								79 (104)	94.5		
Medina Fall	Thies		94 (110)									
Ndioukhane	Thies	74	89 (96)	92.2	74			61	76 (75)		68 (76)	91.9
Niayes	Thies			83.9			49.5			78.2		90.9
Thiès	Thies				48			18				
Thilane	Thies		94 (100)						95 (83)		95 (80)	
Oussoye	Ziguinchor	100			100			100				

PMI Insecticide Susceptibility Summaries

An. gambiae s.l. WHO tube assays, organochlorines and carbamates, (2008-12 shows the most recent data available between 2008 and 2012).

District	Region	DDT			Dieldrin			Bendiocarb		
		2008-2012	2013	2014	2011-2012	2013	2014	2008-2012	2013	2014
Dakar Centre	Dakar	8		13.9	19		7.8	89		8.7
Guediawaye	Dakar	0		1.9	15		18.1	80		64.1
Pikine	Dakar			0.9						34
Bambey	Diourbel		75	39					99 (99)	100
Dioffior	Fatick	52			87			100		
Fatick	Fatick		88						100 (103)	100
Niakar	Fatick		75						100 (114)	
Kaffrine	Kaffrine		77	80		92 (92)	95.9		83 (96)	100
Koungheul	Kaffrine	93 (104)	85	78.4	96		97	99 (102)	100 (87)	100
Maleme Hodar	Kaffrine	54 (99)	90	87	82	97.8	93.8	96 (107)	100 (120)	100
Guinguineo	Kaolack	47 (91)	64.8	67	70			100 (89)	99 (108)	100
Ndoffane	Kaolack		68.6	44.8		87 (100)	78.8		78 (213)	95.3
Nioro	Kaolack	57 (23)	82.1	73.2	96	92 (106)		100 (100)	99 (103)	100
Kedougou	Kedougou	11		13	83		75	94		92.5
Kolda	Kolda			19						92.4
Velingara	Kolda	82 (100)	92	77.3	94			97 (105)	100 (79)	95.4
Barkédji	Louga	82		88.3	96			99		100
Linguère	Louga	89						100		
Gabou (Bakel)	Matam									
Kanel	Matam			82.7						88.9
Ranerou	Matam									
Podor	St. Louis	71			94			98		
Richard Toll	St. Louis	42 (123)	41.4	86.9		72 (104)	92.7	61 (118)	86 (101)	100
Koumpentoum	Tambacounda	87 (93)		86.7		92 (93)		100 (99)	100 (82)	99
Tambacounda	Tambacounda	54		54	91		83	99		93
Mbour	Thies			80.7					94 (96)	98
Medina Fall	Thies		31						100 (99)	
Ndioukhane	Thies	17	47	43.2			77.9	75	100 (76)	93.3
Niayes	Thies		54	37.2					98 (112)	86.7
Thiès	Thies	41						91		
Thilane	Thies		65						100 (80)	
Oussoye	Ziguinchor	94						100		

PMI Insecticide Susceptibility Summaries

An. gambiae s.l. WHO tube assays, organophosphates, (2008-2012 shows the most recent data available between 2008 and 2012).

District	Region	Fenitrothion			Malathion			Pirimiphos-methyl	
		2008-2012	2013	2014	2011-2012	2013	2014	2013	2014
Dakar Centre	Dakar	96		100	100		100		100
Guediawaye	Dakar	100		100	100		100		100
Pikine	Dakar			100					
Bambey	Diourbel							100 (102)	100
Dioffior	Fatick	100			100				100
Fatick	Fatick							100 (101)	
Niakar	Fatick							100 (119)	
Kaffrine	Kaffrine		100 (100)	100		100 (106)	100	100 (99)	100
Koungheul	Kaffrine	100 (96)	100 (90)	100	100 (104)		100	100 (92)	
Maleme Hodar	Kaffrine	100 (122)	100 (98)	100	100 (101)	100 (99)	100	100 (91)	100
Guinguineo	Kaolack	100 (99)	100 (105)		100			100 (105)	100
Ndoffane	Kaolack		100 (102)			100 (107)	100	100 (104)	
Nioro	Kaolack	100 (106)	100 (112)		100 (92)	100 (105)	100	100 (110)	
Kedougou	Kedougou	99		94.5	94		99		
Kolda	Kolda			97.9			100		
Velingara	Kolda	100 (100)	100 (82)		98 (113)			100 (78)	
Barkédji	Louga	100			100				100
Linguère	Louga	100							
Gabou (Bakel)	Matam								98.9
Kanel	Matam								100
Ranerou	Matam								
Podor	St. Louis	100			100				
Richard Toll	St. Louis	100 (155)	100 (107)	100		100 (107)	100	100 (110)	
Koumpentoum	Tambacounda	100 (86)			100 (97)		100	100 (88)	
Tambacounda	Tambacounda	100		97	100		99		
Mbour	Thies							100 (94)	100
Medina Fall	Thies							100 (99)	
Ndioukhane	Thies	86	100 (71)	100			100	100 (66)	100
Niayes	Thies			100			100	100 (106)	
Thiès	Thies	100							
Thilane	Thies		100 (93)					100 (80)	
Oussoye	Ziguinchor	100			100				

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.

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

COMMENTS ON DATA:

Susceptibility data was collected in collaboration with the National Institute for Medical Research, Amani Medical Research Centre and the Zanzibar Malaria Control Program (ZMCP).

Mainland – 2011 tests were performed on adults reared from field-collected larvae in Dodoma, Dar es Salaam, and Magu; all other 2011 tests on field captured adults. 2012-13 tests were performed on adults reared from field-collected larvae.

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 – WHO tube bioassays were conducted on *An. gambiae* s.l. reared from field-collected larvae.

CONCLUSIONS:

- For Zanzibar: *An. gambiae* s.l. is resistant to pyrethroids and DDT, but fully susceptible to carbamates and organophosphates. PBO assays indicate that pyrethroid resistance is mainly metabolic, but the *kdr* mutation has recently been detected.
- 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, and suspected resistance in 3 additional sites.
 3. There is carbamate and organophosphate resistance in Kyela, and probable carbamate resistance in Arumeru and Kondoa, but there is 100% susceptibility to carbamates in all other sites
 4. There is 100% organophosphate susceptibility in all tested sites, with the exception of Kyela; pirimiphos-methyl has not been tested.

PMI Insecticide Susceptibility Summaries

Mainland WHO tube assays for *An. gambiae* s.l.: pyrethroids and DDT. 2011-2012 indicates most recent data from that period.

Mainland	Permethrin .75%		Lambdacyhalothrin .05%		Deltamethrin .05%		DDT 4%	
	2011-2012	2013	2011-2012	2013	2011	2013	2011-2012	2013
Kilombero	85 (80)	83	100 (80)	100	96 (80)	100	99 (100)	100
Kyela	100 (86)	87	100 (83)	93	100 (78)	100	100 (85)	100
Mvomero	100(82)		100 (83)		100 (78)		100 (83)	
Muheza	75.3 (95)	86	81.8 (95)	72	74.5 (95)	87	100 (100)	96
Lushoto	100 (100)		100 (10)		100 (100)		100 (100)	
Handeni	95 (100)		97.9 (92)		92.9 (99)		100 (100)	
Arumeru	74	67	68	34	90.4 (125)	56	92	100
Dodoma	100 (80)		100 (80)		100 (80)		100 (80)	
Tabora	100 (80)		100 (80)		100 (80)		100 (80)	
Dar es Salaam	90.3 (75)		94.8 (79)		96.8 (85)		100 (74)	
Magu (Mwanza Region)	100 (100)	100	100 (25)	78	100 (20)	100	80 (20)	100
Muleba (Kagera Region)	100 (80)		85 (80)		85 (80)		100 (60)	
Babati	99 (123)	81	100 (125)	65	96 (125)	78	100 (100)	100
Moshi	60	60	56	57	71.8 (533)	54	99	98
Sumbawanga	100		100				100	
Manyoni	100		100				100	
Ngara (Kagera Region)	60	100	54	100		100		100
Geita (Mwanza Region)	80		78				98	
Tarime	100		99				100	
Bariadi	97		91				97	
Kigoma	100		100				100	
Bagamoyo	97	100	100	41		100	100	100
Kahama		100		100		100		100
Kilosa		96		78		98		97
Kinondoni		85		78		89		84
Kasulu		100		89		98		96
Kondoa		91		90		84		100
Mbozi		87		89		100		100
Musoma R		100		75		100		100
Singida		100		100		100		100
Uyui		100		100		100		100

PMI Insecticide Susceptibility Summaries

Mainland WHO tube assay data, *An. gambiae* s.l.: carbamates and organophosphates. 2011-2012 indicates most recent data from that time period.

Mainland	Bendiocarb .1%		Propoxur .1%	Fenitrothion 1%	
	2012	2013	2011	2011-2012	2013
Kilombero		100	98.8 (80)	100 (123)	100
Kyela		82	98.8 (79)	98.8 (80)	87
Mvomero			98.8 (80)	100 (81)	
Muheza		100	100 (100)	100 (100)	
Lushoto			100 (100)	100 (100)	
Handeni			100 (100)	100 (100)	
Arumeru	97	97	100 (125)	100	100
Dodoma			100 (80)	100 (80)	
Tabora			100 (80)	100 (80)	
Dar es Salaam			100 (68)	100 (60)	
Magu (Mwanza Region)		100	100 (90)	100 (80)	100
Muleba (Kagera Region)			100 (80)	100 (60)	
Babati		100	100 (125)	100 (100)	100
Moshi	98	100	99.8 (338)	98	100
Sumbawanga	100			100	
Manyoni	100			100	
Ngara (Kagera Region)	100	100			100
Geita (Mwanza Region)				100	
Tarime	100			100	
Bariadi	100			100	
Kigoma	100			100	
Bagamoyo	100	100		100	100
Kahama		100			100
Kilosa		100			100
Kinondoni		100			100
Kasulu		100			100
Kondoa		96			100
Mbozi		100			100
Musoma R		100			100
Singida		99			100
Uyui		100			100

PMI Insecticide Susceptibility Summaries

Zanzibar: WHO tube assays on *An. gambiae* s.l., from Haji et al. 2013.

Zanzibar	Permethrin .75%		Lambdacyhalothrin .05%		Deltamethrin .05%		DDT 4%		Bendiocarb .1%		Malathion 5%
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2011
Unguja	99 (100)		95 (100)		99 (100)				100 (100)		
Pemba	57 (89)	51 (100)	46 (74)	9 (100)	42 (100)	36 (100)	100 (98)	100 (100)	100 (82)	100 (100)	100 (100)

Additional 2013 data from FY 2015 MOP:

Pemba (4 sites): permethrin resistance in 3 sites (63-76% mortality); deltamethrin resistance in 1 site (13% mort.); lambdacyhalothrin resistance in all sites (13-82% mort.); DDT resistance in 2 sites (37-63% mort.). 100% susceptibility to pirimiphos-methyl and bendiocarb.

Unguja (5 sites): permethrin resistance in 1 of 2 sites tested (63% mortality); lambdacyhalothrin resistance in 4 sites (60-76% mort.). 100% susceptibility to pirimiphos-methyl and bendiocarb.

PBO synergist assays show that pyrethroid resistance is due to metabolic mechanisms, but *kdr* target site insensitivity was also recently detected on Pemba.

PMI Insecticide Susceptibility Summaries

UGANDA

PMI is the sole supporter of IRS in Uganda. 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). Since 2009, PMI has 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 2014, IRS was suspended in 5 districts, and began in two new high-burden districts (2014: Agago, Pader, Gulu, Oyam, Kole, Lira, Tororo).

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 in 2010. In 2014, long-lasting organophosphates were used, in one round of spraying.

COMMENTS ON DATA:

Susceptibility data was collected in collaboration with the National Malaria Control Program.

2008: Susceptibility tests were conducted on *An. gambiae* s.l. reared from field-collected larvae.

2009, 2011, 2013: 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.

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. 2008/9-2011 shows the most recent data available between 2008/9 and 2011.

District	Lambdacythothrin .05%		Permethrin .75%		Deltamethrin .05%		Cyfluthrin .15%	Alpha-cypermethrin .05%		Etofenprox .5%	
	2008-2011	2013	2009-2011	2013	2011	2013	2009-2011	2011	2013	2009-2011	2013
Oyam	40 (103)										
Apac	30 (100 L)	56 (100 L)	31(100 L)	85 (100L)	23 (100 L)	82 (100 L)	40 (100 L)	69 (100 L)		56 (100)	84 (100 L)
Kitgum	65 (100 L)		4 (100 L)		55 (100)	58 (100 L)	14 (100 L)			92 (100)	
Wakiso	30 (100 A)	21 (100 L)	86 (80 L)	24 (100 L)	45 (100 A)	44 (100 A)		98 (100 L)	60 (100 A)	77 (100)	
Kanungu	53 (100 A)	27 (100 A)	27 (100 A)	31 (100 A)	86 (100 A)	53 (100 A)	92 (100 A)	100 (100 A)	61 (100 A)	75 (100)	
Hoima	89 (100)		69 (100 A)		93 (100)	18 (100 L)	88 (100 A)			87 (100)	
Tororo	34 (100 A)	26 (100 L)	40 (100 A)	45 (100 A)	63 (100 A)	37 (100 L)	27 (100 A)	89 (100 A)	42 (100 A)	41 (100)	

An. gambiae s.l., WHO tube assay results: organochlorines, carbamates, and organophosphates. (A) indicates mosquitoes from adult collections were used, (L) indicates larval collections. 2008/9-2011 shows the most recent data available between 2008/9 and 2011.

District	DDT 4%		Propoxur .1%		Bendiocarb 0.1%		Malathion 5%		Pirimiphos methyl 1%	
	2008-2011	2013	2009-2011	2013	2008-2011	2013	2009-2011	2013	2009-2011	2013
Oyam	24 (129)				100 (115)					
Apac	91.5 (200 L)	95 (100 L)	100 (100 L)		100 (200)	99 (100 L)	99 (100 L)		100 (200)	100 (130 L)
Kitgum	94 (100 L)	81 (100 L)	100 (100 L)		100 (15)	100 (100 L)	100 (100 L)		100 (100)	100 (100 L)
Wakiso	23 (100 A)	10 (100 L)	100 (100 L)	92 (100 A)	99 (100)	85 (100 L)		100 (75 A)	100 (100)	100 (100 L)
Kanungu	36 (100 L)	59 (100 A)	100 (40 L)	100 (100 A)	96 (100)	100 (100 A)	100 (100 A)		100 (100)	100 (80 L); 100 (100 A)
Hoima	53 (100)	34 (100 L)	100 (100 A)		99 (100)	95 (100 L)	100 (100 A)		100 (100)	100 (100 L)
Tororo	45.5 (200 A)	41 (100 A); 37 (100 L)	81 (100 A)	95 (100 A)	90 (100)	94 (115 A); 100 (100 L)	100 (100 A)	100 (50 A)	100 (200)	100 (100 L); 100 (109 A)

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).

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 2013-2014 was transitioned to organophosphate only.

COMMENTS ON DATA:

Data from 2009-2012 was collected in collaboration with the Zambia Integrated Systems Strengthening Program (ZISSP) and the National Malaria Control Centre (NMCC). Data from 2014 was collected by Abt/AIRS. Tested mosquitoes were either reared from field-collected larvae or were offspring of field-collected, blood fed adults. Data from 2009-11 data have been partially published in Chanda et al. 2011.

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.⁴

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., bendiocarb has only been recently been tested in Luapula and Northern; there is 80-100% susceptibility. Older data from Copperbelt shows susceptibility.
- *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.

⁴ 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	Deltameth.	Permethrin	DDT	Bendiocarb	Pirimiphos-methyl
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

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

Province	District	Settlement	Deltamethrin	Permethrin	DDT	Bendio	Pirimiphos-methyl	alphacypermeth	λ-cyhalothrin	dieldrin
Central	Mkushi	Twatasha	100 (54)	42 (50)	100 (37)	81.5 (27)	100 (34)			
Central	Serenje	Chibobo	60 (30)	36 (25)	100 (57)	78 (45)	100 (25)			
Central	Serenje	Chipundu	68 (25)	60 (30)		84 (50)	100 (11)			
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)		100 (25)	89.7 (29)	100 (75)			
Luapula	Milenge	Talayi	67 (100)		100 (28)	80 (60)	100 (80)			
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	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)	98 (94)	66.9 (130)	100 (140)
Northern	Kasama	Chishimba	34 (104)	100 (113)	100 (40)	78 (99)	100 (38)			
Northern	Mungwi	Chitimukulu	96 (127)			91 (156)	100 (99)			

PMI Insecticide Susceptibility Summaries

Historic data, *An. gambiae* s.l. 2009-2012 WHO tube assays. For each site/insecticide, the most recent data point from 2009-2012 is shown.

^ Indicates data from LSTM for ZISSP (April and Oct 2012 reports)

Province	District (site) *Sites with <i>kdr-west</i> mutation	Deltamethrin	Permethrin	Etofenprox	λ-cyhalothrin	DDT	Malathion	Bendiocarb
Central	Kapiri Mpohi (Chipepo)*	42 (43)						
Central	Mumbwa (Myooye)*	93 (74)				67 (73)		
Central	Kabwe (Mukobeko)	100 (16)						
Copperbelt	Ndola (Chipulukusu)*	14 (96)	29 (41)	98.4 (43)	92 (26)	43(428)	100(27)	
Copperbelt	Ndola (Mushili)*	21 (180)	55 (31)			58 (244)	100 (47)	100 (154)
Copperbelt	Ndola (Twapia)*					67 (135)		
Copperbelt	Luanshya	48(25)	68 (40)	51 (100)	67 (45)	2 (100)	100 (27)	
Copperbelt	Kitwe*	75 (124); 21 (332)^	34 (118)^	5 (101)^	84 (38)^	2 (100)	100 (387)	99 (527); 100 (14)^
Copperbelt	Chililabombwe	72 (65)		100 (19)	71 (45)	58 (45)	100 (38)	
Copperbelt	Mufulira	83 (190)^		87 (111)^	30 (20)	5 (22)^		99 (117)
Copperbelt	Masaiti							95 (60)
Luapula	Nchelenge	80 (5)				33 (3)		
Lusaka	Luangwa (Chisobe)	100 (102)						
Lusaka	Luangwa (Nyamankalo)	91 (11)						
Northwestern	Solwezi (Kizhingezhinge)*	95 (105)				4 (157)		
Northwestern	Solwezi							100 (20)
Northern	Kasama	39 (80)^						64 (11)^

PMI Insecticide Susceptibility Summaries

Historical data: *An. funestus* s.l. WHO tube assays, 2009-2012. For each site/insecticide, the most recent data from 2009-2012 is shown.

^ indicates data from LSTM for ZISSP (April and Oct 2012 reports)

Province	District (site)	Deltamethrin	DDT	Permethrin	Etofenprox	Malathion	λ-cyhalothrin	Bendiocarb
Central	Chibombo (Chibombo)	89 (9)						
Central	Kabwe (Mukobeko)	96 (26)						
Central	Chibombo (Mulungushi)					100 (7)		
Central	Mumbwa (Myooye)	96 (27)	94 (62)					
Copperbelt	Kitwe							99 (80)
Luapula	Nchelenge	94 (82)	97 (87)					
Luapula	Kawambwa	46 (244)^						0 (17)^
Northern	Kasama	16 (206)^			5 (138)^			80 (142)^
Lusaka	Luangwa (Chisobe)	64(50)				100 (15)	51 (45)	
Lusaka	Chongwe (Kabulongo)	80 (15)	100 (14)					
Lusaka	Kafue	96 (23)	98 (90)					
Lusaka	Luangwa	43 (108)^	96 (246)^		27 (490)	100 (101)^	47 (51)^	44 (289)^
Lusaka	Chongwe (Mufweshya)	100 (18)	100(21)					
Lusaka	Luangwa (Nyamankalo)	81 (87)	88 (33)					
Lusaka	Chongwe (Rufunsa)	67 (66)						
Lusaka	Chongwe (Shikabeta)	35.7 (42)	100 (51)			100 (63)		78.3 (42)
Southern	Mazabuka (Mwanachingwala)	82 (22)						
Southern	Mazabuka	20 (35)	100 (10)	91 (11)				
Southern	Gwembe	41 (60)^					19 (75)^	
Eastern	Katete	37 (67)^	100 (190)	61 (131)	43 (282)^	100 (225)	27 (106)^	72 (302); 12 (17)^
Eastern	Chadiza	30 (37)						
Eastern	Chipata	67 (100)^	100 (20); 100 (87)^		82 (115)^		92 (126)^	9 (140)^; 71 (118)^
Western	Kaoma	77 (290)^	100 (116)^	31 (738)^	85 (220)^	63 (133)^	10 (119)^	98 (45); 47 (152)^
Western	Senanga		100 (30)					
Northwestern	Solwezi							100 (20)
Muchinga	Isoka	94 (50)^						5 (21)^
	Moonga							0 (20)^

PMI Insecticide Susceptibility Summaries

ZIMBABWE

In 2012, PMI supported IRS in 17 districts in 3 provinces (Mashonaland East, Mashonaland West, & Manicaland). In 2013, PMI support for IRS was expanded to 25 districts. In 2014, PMI implemented IRS in 4 districts in Manicaland Province (Nyanga, Mutasa, Chimanimani, and Mutare), and the government has taken over 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 in 2014. Government-supported IRS outside of Manicaland 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*.

Prior data: WHO tube assays were conducted in 2011 & 2012. All populations showed 100% susceptibility to all insecticides.

2011: DDT, permethrin, cyfluthrin, etofenprox, lambda-cyhalothrin, and deltamethrin were tested in: Masakadza and Kamhororo (Midlands Province), Chilonga (Masvingo), Checheche (Manicaland).

2012: DDT, bendiocarb, lambda-cyhalothrin, and malathion were tested in:

Kwekwe and Gokwe South (Midlands), Bikiti and Chiredzi (Masvingo), Mutasa and Mutare (Manicaland), Rushinga and Centenary (Mashonaland Central), Mudzi and Upper Mash. Project (Mashonaland East), Hurungwe and Sanyati (Mashonaland West), Matobo and Breitbridge (Matebeleland South), Lupane and Binga (Matebeleland North).

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, but susceptibility elsewhere.
- 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. gambiae* s.l. and *An. funestus*.

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%	DDT 4.0%		Bendiocarb 0.1%		Pirimiphos-methyl 1%	
		2013	2014	2013	2014	2014	2013	2014	2013	2014	2013	2014
Mashonaland Central	Rushinga		100 (69)		100 (118)	100 (50)		100 (125)		100 (53)		100 (52)
Masvingo	Chiredzi				48 (100)	100 (24)		84 (13)		100 (48)		100 (95)
Matebeleland South	Beitbridge				86 (113) #	98 (50)		91 (207)		84 (100)		100 (100)
Matebeleland North	Binga				81 (88)			100 (88)		100 (89)	100 (93)	
Midlands	Gokwe South		100 (67)		100 (92)			100 (99)		100 (98)		100 (110)
Mashonaland East	Mutoko	100 (30)	100 (25)	91 (35)	100 (47)		100 (18)	100 (25)	100 (30)		100 (15)	100 (46)
Mashonaland West	Hurungwe	94 (29)		90 (31)	87 (113)	96 (50)	100 (24)	100 (95)	100 (42)	88 (50)	100 (21)	100 (99)
	Kadoma				72 (90)			100 (50)		91 (35)		100 (50)
Manicaland (<i>An. funestus</i>)	Mutasa	65 (49)*		24 (83)*	0 (20)	16 (19)	100 (55)*		70 (67)*	6 (18)		100 (20)
	Mutare				7 (46)	3 (33)		100 (36)		23 (26)		100 (30)

* 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

Acknowledgements

Abt Associates collected resistance data in Angola, Benin, Ethiopia, Ghana, Liberia, Madagascar, Mali, Mozambique, Nigeria, Rwanda, Uganda, Zambia, and Zimbabwe during 2013-2014.

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

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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)

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Mali – Dr. Mamadou B. Coulibaly (MRTC)

Nigeria – Dr. Georgina S. Mwansat (University of Jos)

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Tanzania – William Kisinza (Amani Medical Research Centre); Juma H. Mcha (ZMCP)

Uganda – Michael Okia (NMCP)

Zambia – (NMCC)

Zimbabwe – (NMCP & NIHR)