PNGIMR MALARIA SENTINEL SURVEILLANCE PROGRAM

REPORT ON

TIME-TREND DATA DERIVED FROM MALARIA RAPID DIAGNOSTIC TESTING IN SENTINEL HEALTH FACILITIES, 2008-2015

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EXECUTIVE SUMMARY

This report presents findings from longitudinal malaria surveillance conducted in seven sentinel health facilities located across Papua New Guinea (PNG) during the period 2008 to 2015. Data are derived from malaria rapid diagnostic tests (mRDTs) completed with outpatient cases who report current or recent (past three days) fever upon presentation to the respective health facilities. A full population census was completed with the catchment population of four of these health facilities allowing calculation of an annual crude malaria incidence rate in these sites. In addition, the mean number of malaria cases and mRDT positivity rates were calculated on a monthly basis across all seven sites. This report presents time-trend data on all three measures. Key findings include:

- Pooled data from across the four health facility surveillance sites in which the population census is known indicates a consistent reduction in crude malaria incidence during the four year period between August 2010 and July 2014 (from 205 to 48 cases per 1000 person years/per year); however, the incidence rate appears to have plateaued at just over 40 cases per 1000 person years/per year since that time.

- The mean mRDT positivity rate across the four pooled surveillance sites reduced from 42% to 21% between August 2010 and July 2014 and then plateaued at approximately that rate (22%).

- Site-specific data indicate considerable intra- and inter-site variation in crude malaria incidence, frequency of malaria cases and mRDT positivity rates reported over time. Ranging from immediate and sustained reductions on all three measures following initial distribution of long-lasting insecticidal nets (LLIN) to fluctuating and apparently resurgent malaria transmission despite multiple LLIN distribution rounds.

These trends highlight the apparent fragility of LLIN impact in some communities in PNG and suggest that rapid increases in incidence can and do occur despite multiple LLIN distributions based on the current three year replacement cycle. The pooled crude malaria incidence data further suggest that current malaria control interventions, delivered via current

mechanisms and at current intensity, may be close to reaching their maximum impact threshold.

1. INTRODUCTION

Papua New Guinea (PNG) is a malaria endemic country with a mixed history of malaria control. A national eradication campaign based on indoor residual spraying (IRS) and mass drug administration (MDA) achieved remarkable reductions in malaria prevalence between the late 1950s and early 1970s [1]. However, elimination was not achieved, program funding and activity went into decline and malaria transmission quickly rebounded to levels equal to or greater than the pre-elimination period [2-3]. The next major attempt to combat malaria did not commence until 2004 when PNG secured a 'Round 3' grant from the Global Fund to Fight AIDS, Tuberculosis and Malaria (GF) to finance a free countrywide distribution of long lasting insecticidal mosquito nets (LLIN). This was followed by a 'Round 8' GFgrant for the period 2009-2014 and a further GF grant for the period 2015-2017. Collectively, these GF grants have supported (and continue to support) repeat free countrywide LLIN distribution, the provision of malaria rapid diagnostic tests (mRDTs) and artemisinin-based combination therapies (ACTs) in the formal health care network, behaviour change communication campaigns supporting LLIN use and prompt treatment-seeking for febrile illness and home-based management of malaria (HMM) programs in selected districts [4].

The Papua New Guinea Institute of Medical Research (PNGIMR) was contracted to provide a range of monitoring and evaluation (M&E) activities in support of the PNG National Malaria Control Program (NMCP) on all three GF grants. A key component of the PNGIMRs evaluation of both the Round 3 and Round 8 GF grants was the establishment and maintenance of malaria sentinel surveillance sites across the country. These surveillance sites were designed to support longitudinal monitoring of morbidity trends alongside intervention coverage indicators (e.g. LLIN ownership) in known populations. The resulting data complement findings from repeat cross-sectional surveys at the household and health facility level in randomly selected villages nationwide. Pooled data from four of these surveillance sitesinformed calculations of crude clinical malaria incidence rates reported during the 2009-2014 Round 8 grant [5].

Since 2004, the PNG NMCP has largely been based on the delivery of generalised malaria control interventions designed to achieve universal coverage of LLINs and universal access to effective malaria treatment. Key impact indicators reported by PNGIMR indicate this approach has achieved remarkable success: malaria parasite prevalence in the general population has decreased from 12.4% to 1.8% between 2009 and 2014, clinical incidence has decreased from 205 to 48 cases per 1000 person years/per year over the same period and a reduction in the all-cause mortality rate among children under five has been observed [5]. However, reductions in malaria prevalence and incidence are unlikely to have been uniformly experienced across PNG and the substantial overall reductions observed to date will inevitably plateau as the 'generalised' control interventions approach their maximum impact potential. At that point, new 'targeted' malaria control strategies and interventions will be needed in order to identify and effectively respond to residual malaria transmission as well as to intensify the malaria control efforts in those communities in which relatively high malaria transmission persists. Malaria sentinel surveillance, especially in countries like PNG where the capacity of the National Health Information System (NHIS) to providedetailed and accurate data remains limited, is essential to determining when the PNG NMCP may be approaching this maximum impact threshold and to highlighting heterogeneity in malaria trends in different settings within PNG.Sentinel surveillance sites can complement routine statistics with in depth data thatcannot easily be generated through the NHIS, including trends in malaria species composition (based on microscopy or PCR), detailed age breakdown of clinical cases, or molecular markers of drug resistance, and extend the health facility-based NHIS to cover population-based measurements.

Accordingly, this report provides an update on a key impact indicator for the PNG NMCP – annual number of mRDT positive cases per 1000 person-years - for the period August 2014 to July 2015. In addition, it presents detailed time-trend data for all seven sentinel surveillance sites on malaria cases and mRDT positivity rates for the period 2008 to 2015. It is anticipated that the updated incidence data will allow an assessment of the current level of NMCP impact whilst the site-specific data will inform discussion on sub-national heterogeneity in malaria transmission and impact of current control measures in PNG.

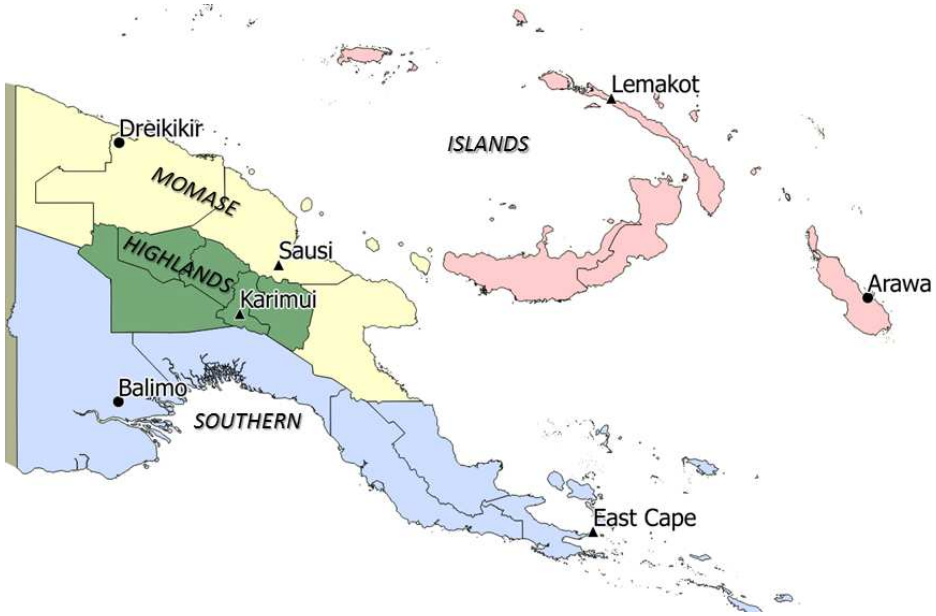
2. METHODOLOGY

This report presents data from seven malaria sentinel surveillance sites established during PNGIMRs evaluation of the Round 3 and Round 8 PNG/GF NMCP. The sites were established as a component of a larger M&E program which is described elsewhere, inclusive of a full description of the malaria sentinel surveillance methodology [6]. The following description is a summarized version of this previously published account. It should be noted that GF financial support for PNGIMRs malaria sentinel surveillance site program ceased in March 2015. PNGIMR has sought to maintain five of these sites through alternative funding, but their viability beyond December 2015 remains uncertain at this point. This report, and planned complementary reports (detailing additional analyses of malaria sentinel surveillance data collected between 2010 to 2015), are produced at PNGIMRs expense and reflects an institutional commitment to continued support of the PNG NMCP.

Study Sites

Sentinel site locations were purposely selected considering accessibility of the site, local malaria epidemiology, presence of a functioning health centre and its case load and estimated catchment population. A total of seven sites were selected, two each located in Southern, Momase and Islands regions and one located in the Highlands (Figure 1). Two of these sites, Sausi and Dreikikir, were established in 2008 as a part of PNGIMRs evaluation of the Round 3 PNG/GF NMCP. The remaining five sites were established in 2010/11 during the Round 8 PNG/GF NMCP. Health facility morbidity surveillance (described below) is carried out at all seven sites. Community-based morbidity surveillance, inclusive of repeat cross-sectional household surveys and population demography, is restricted to four sites (indicated on Figure 1). The process of community surveillance is not described herein as, other than population count (used as a denominator in malaria incidence rate calculations), this report is restricted to data collected at the health facility level. Entomological surveys have been completed at four sentinel sites during the same period. The entomological data will be presented in a dedicated report at a future time point.

Figure 1. Location of the PNGIMR Malaria Sentinel Surveillance Sites



▲ Sites with community surveillance ● Sites without community surveillance

Health Facility Surveillance Procedures and Instruments

All outpatient cases and admissions to the sentinel health facilities are screened for current or recent (past three days) fever. A capillary blood sample is collected from all patients who screen positive for current/recent fever for on-the-spot diagnosis by mRDT, preparation of thick and thin blood film for microscopic diagnosis and determining Hb level using a HemoCueHb 201+ Analyser. Demographic details of the patient are recorded in a one-page form alongside clinical signs and symptoms, previous health facility attendance and drug intake, axillary temperature, body weight and outcomes of the RDT and Hb measurement. Results of the clinical assessments are also recorded in the patient's clinic book. Following this procedure, the patient is transferred to a health facility staff member for further examination and treatment following routine procedures established by the facility. The final diagnosis and any treatment by the health facility clinician are recorded.

Data Analysis

All patient case record forms are sent to PNGIMR, Goroka for data entry and long-term storage. All forms are double entered into a DMSys database for subsequent analysis. Microscopic diagnosis of malaria is performed at PNGIMR and each slide is read

independently by at least two microscopists following established protocols. In cases of disagreement between a first and second read, a third independent read is completed by an expert microscopist. Microscopy data are not presented in this report, although will be included in future reports. The annual crude malaria incidence rates presented in this report are calculated from mRDT-confirmed malaria cases presenting to four sentinel site health facilities and the respective catchment population. Time trend data pertaining to the mean number of mRDT positive cases per month and the mean mRDT positivity rate are also presented for each of the seven sentinel sites. Two sites, Arawa in the Autonomous Region of Bougainville and Balimo in Western Province, were closed in March 2015as a consequence of GFs decision to not renew their financial support for this program. Accordingly, time-trend data ends at this time point in these two sites.

3. RESULTS

Clinical Incidence

Figure 2 presents the pooled crude malaria incidence rate across five time periods (Aug-Jul, in five consecutive years) in the four PNGIMR sentinel sites in which full population censuses were conducted on multiple occasions during the surveillance period. As shown, a consistent reduction in crude malaria incidence was evident across the pooled data in the four year period between August 2010 and July 2014; however, the incidence rate appears to have plateaued at just over 40 cases per 1000 person years/per year since that time.

Figure 2. Time trend in clinical incidence, pooled data from 4 sentinel sites

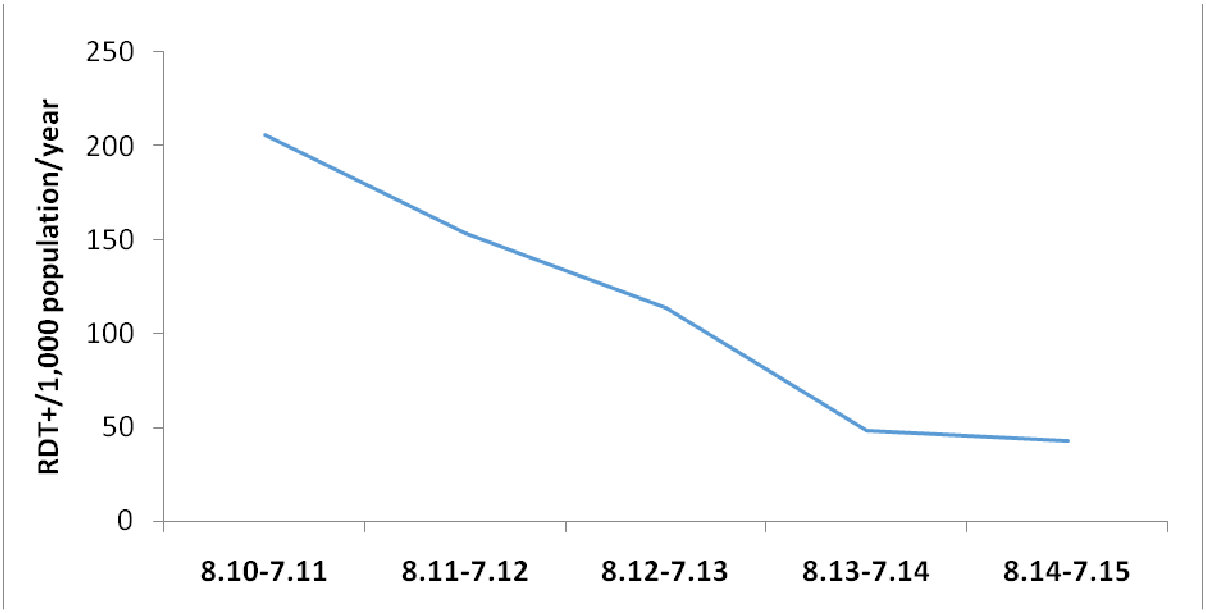


Figure 3 presents the crude malaria incidence rate across the same five year period for each of the four sentinel surveillance sites that collectively inform the pooled data presented in Figure 2. These data highlight the substantial inter- and intra-site variability in crude incidence rates across time. Karimui is marked by a substantial reduction in crude incidence rate between time points one and two and a consistent low rate since that time. This contrasts with a gradual reduction in Sausi across the first two time points and then a steady increase in crude incidence rate since that time. Lemakot and East Cape demonstrate a similar pattern

reflective of the pooled data, but even in these sites fluctuations in the crude malaria incidence rate are observed.

Figure 3. Time trend in clinical incidence by site

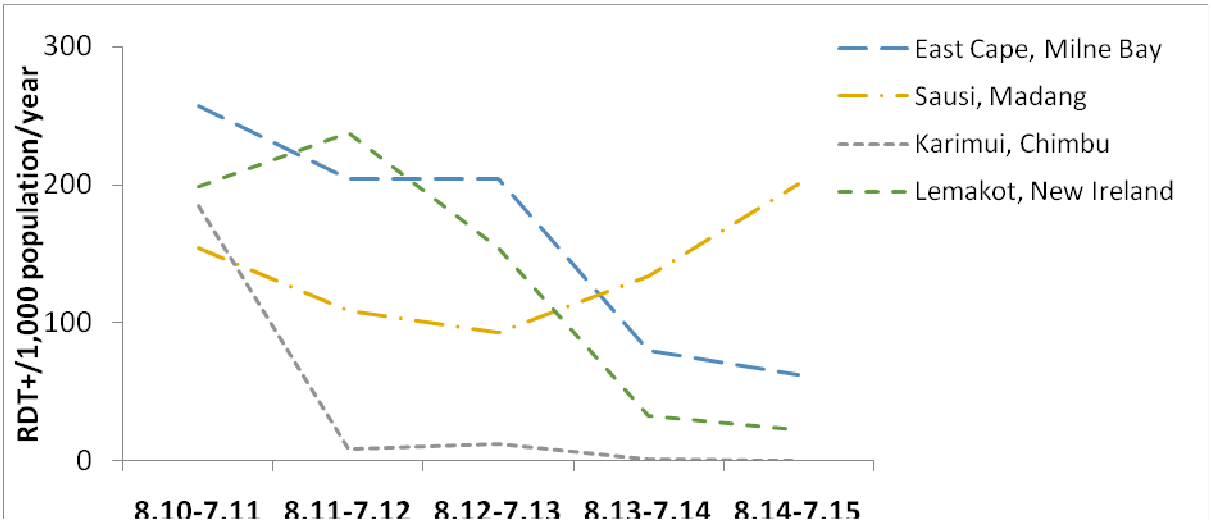
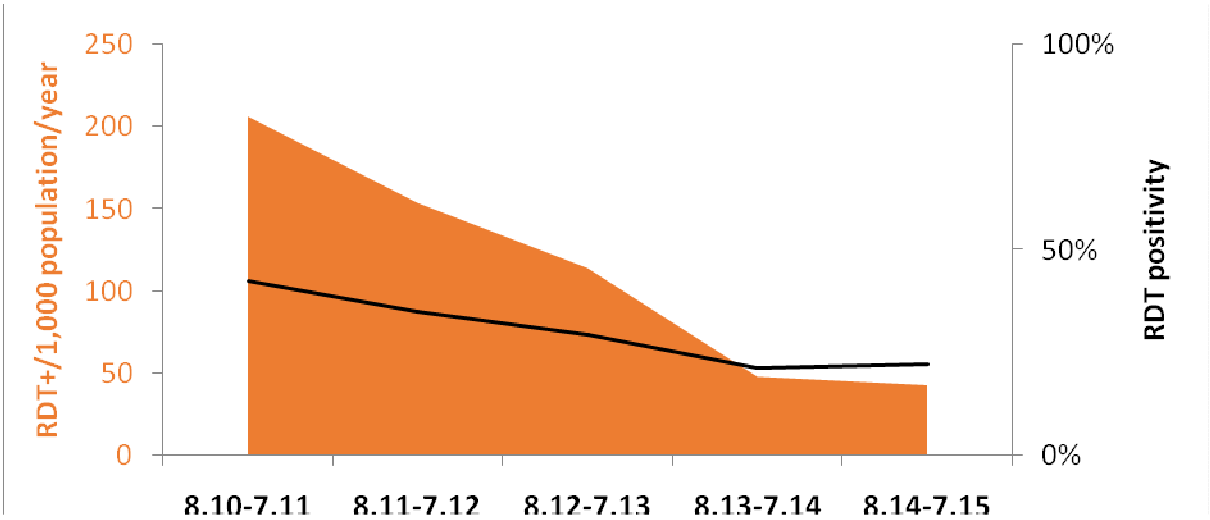


Figure 4 presents the mean RDT positivity rate across the four pooled sentinel surveillance sites (black line) against the crude malaria incidence rate (shaded area). As can be seen, the mean RDT positivity rate gradually reduced from 42% to 21% between the first and fourth time period and plateaued at approximately that rate (22%) over the final 12-month period.

Figure 4. Time trend in RDT positivity rate,pooled data from 4 sentinel sites

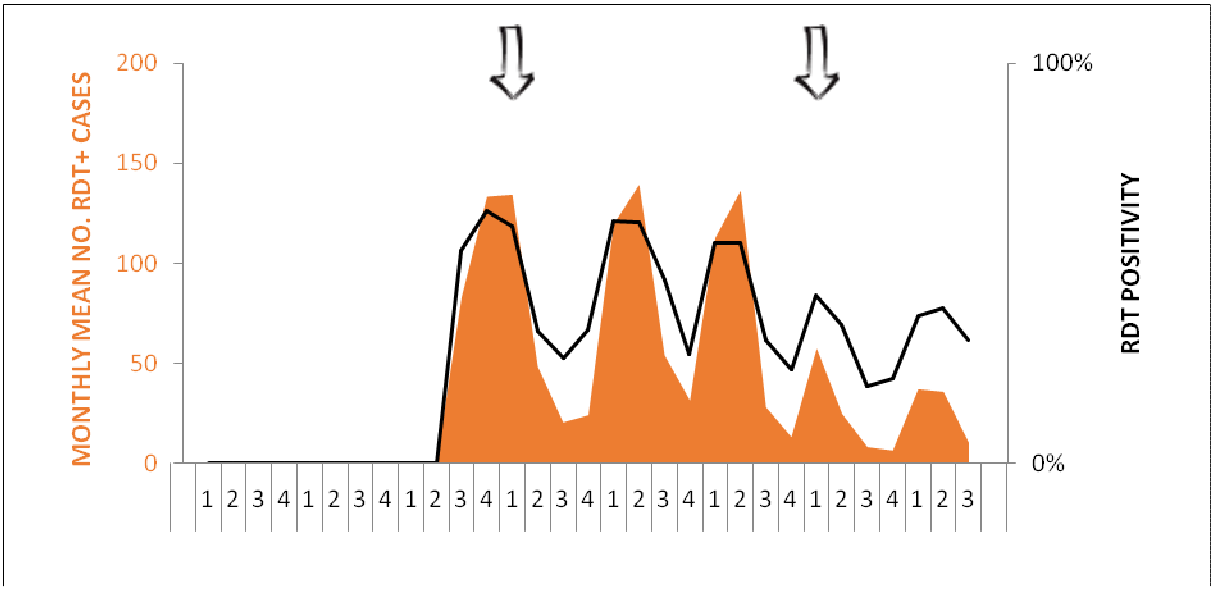


Malaria Cases per Month & RDT Positivity Rates

Figures 5 to 11 present the mean monthly number of RDT positive malaria cases by quarter and the mean RDT positivity rate for each one of the seven PNGIMR sentinel surveillance sites. The timing of LLIN distribution is represented by arrows on each Figure to allow some

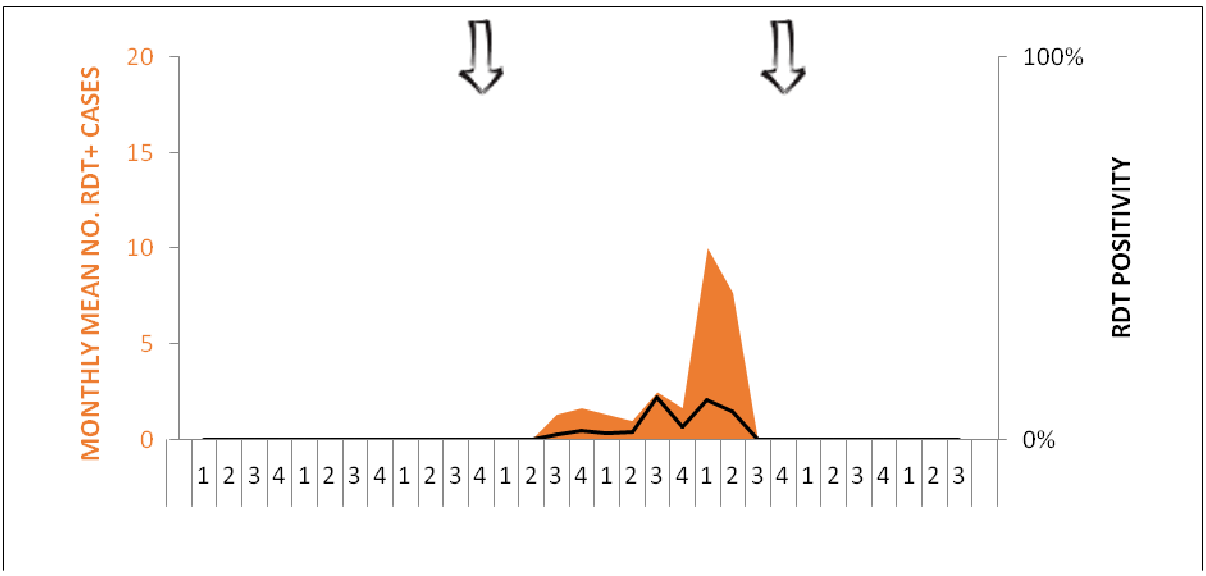
assessment of correlationof LLIN distribution with the reported data. The data informing each Figure are presented in Appendix A.

Figure 5. East Cape, Milne Bay Province



East Cape demonstrates substantial, but consistent seasonal variation in both the number of malaria cases per month and RDT positivity rates. The impact of LLINs appears to have been greater following the second 'Round 8' distribution round as compared to the first.

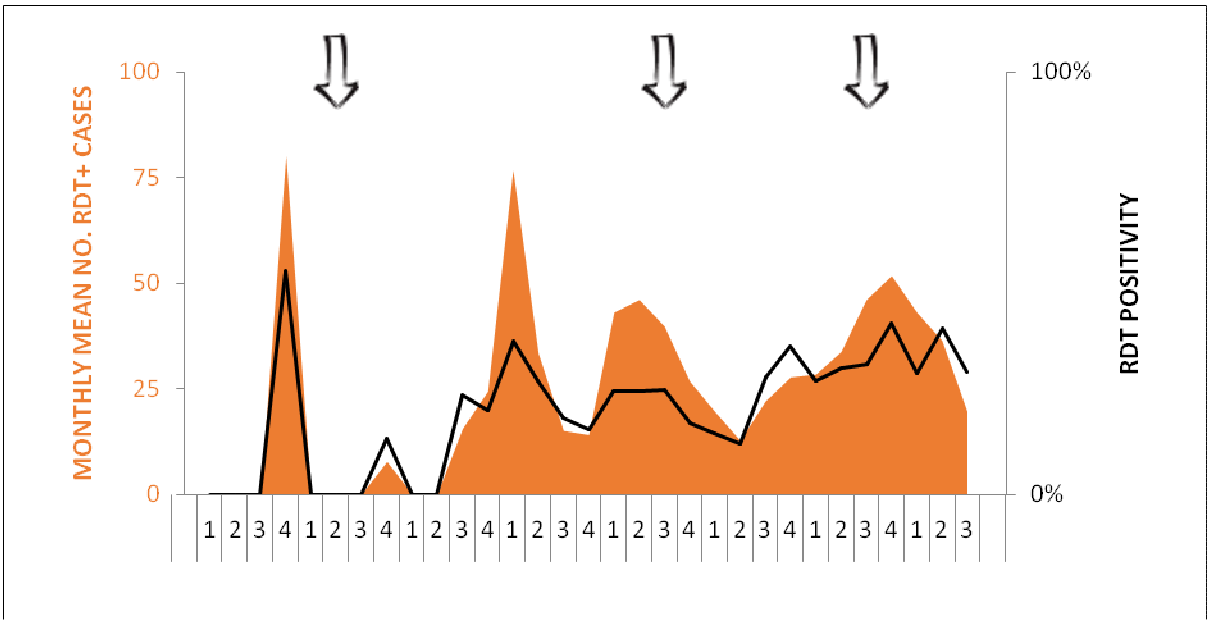
Figure 6. Balimo, Western Province



The Balimo time-trend is less complete than other sites and is indicative of a possible resurgence of malaria cases approximately two and half years post the first distribution.

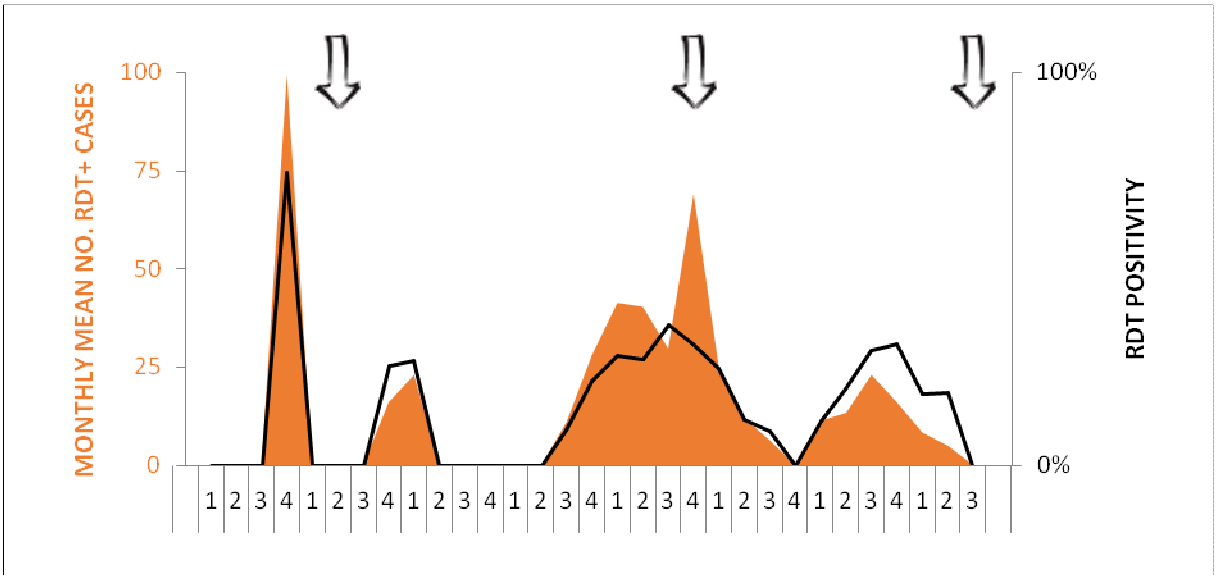
However, a dramatic decrease was observed immediately prior to the second LLIN distribution and was maintained up until the closure of this site (March, 2015).

Figure 7. Sausi, Madang Province



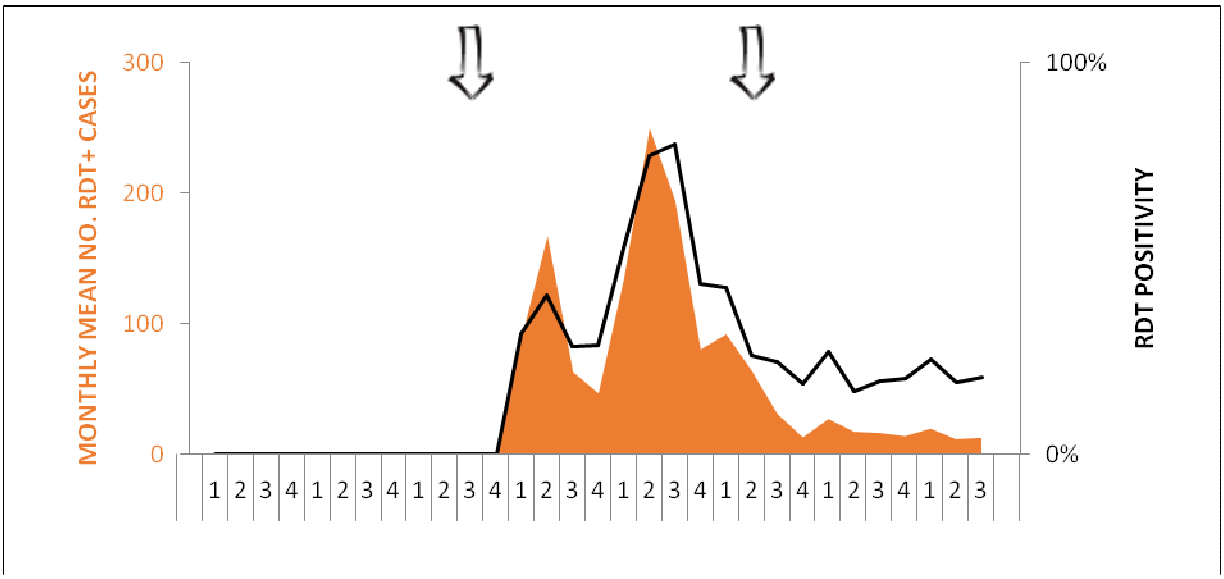
The Sausi time trend is characterised by consistent seasonal variation in malaria cases and RDT positivity. A decline on both measures was apparent following the initial LLIN distributionalthough the initial decline was followed by a general increase prior to the second LLIN distribution and subsequent distributions appear to have had less impact.

Figure 8.Dreikikir, East Sepik Province



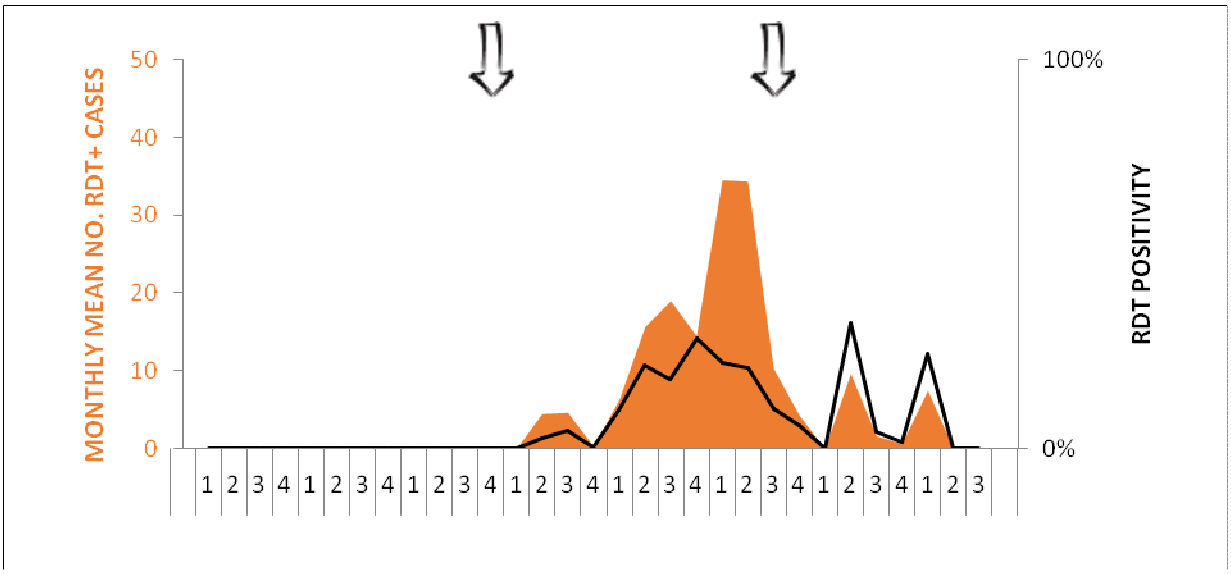
The Dreikikir time trend is suggestive of a marked reduction in malaria cases and RDT positivity following the first round of LLIN distribution and then a resurgence towards the end of the first distribution cycle. A similar resurgence was not apparent towards the end of the second LLIN distribution.

Figure 9.Lemakot, New Ireland Province



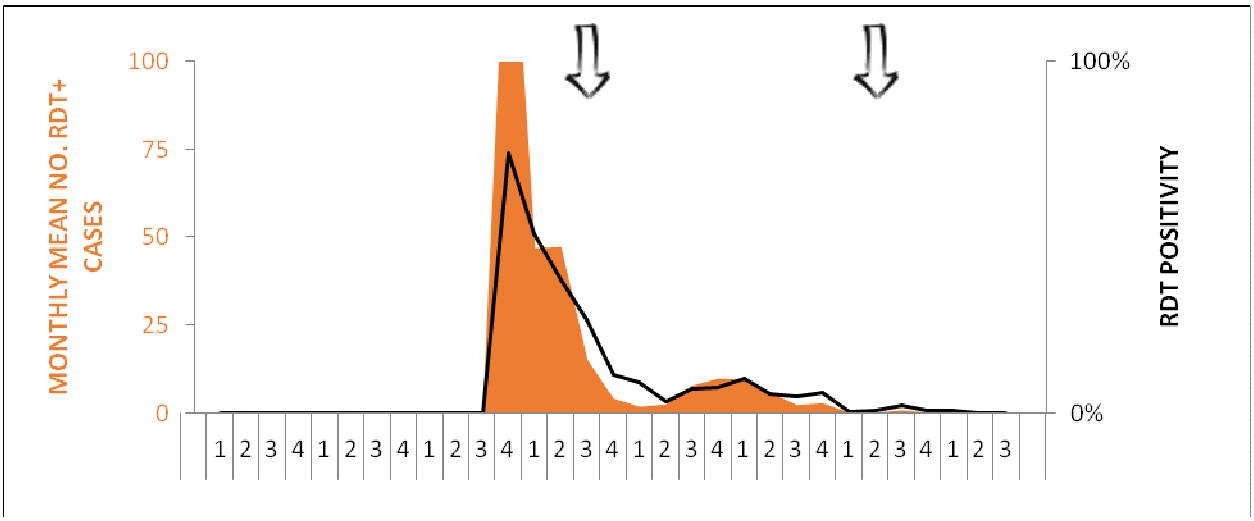
The Lemakot time trend suggests a substantial resurgence in malaria cases and RDT positivity rates approximately two years post the initial LLIN distribution. Malaria cases have been consistently lower following the second LLIN distribution, although the decreasing trend was observed prior to the second distribution taking place.

Figure 10. Arawa, Autonomous Region of Bougainville



The Arawa time trend further displays a pattern of a reducing number of malaria cases and RDT positivity rates immediately after LLIN distribution followed by a resurgence towards the end of the distribution cycle.

Figure 11. Karimui, Chimbu Province



Surveillance in Karimui commenced during the end stages of a major malaria outbreak. The data indicate a substantial and sustained reduction in the number of malaria cases and RDT positivity rates following the first LLIN distribution.

4. DISCUSSION

The PNG NMCP has had undoubted success since GF support commenced in 2004. General population malaria prevalence data, pooled clinical incidence data from malaria sentinel surveillance sites and all-cause mortality rates in children under five have all decreased substantially since independent measurement commenced in 2008 [5]. The data presented in this paper were designed to provide a further update on clinical incidence for the period August 2014 to July 2015 and, drawing on time-trend data from across all seven PNGIMR malaria sentinel surveillance sites, provide a more nuanced examination of the changing malaria epidemiology in PNG. The reported data highlight two issues of note.

Firstly, the pooled crude malaria incidence rate for the period August 2014 to July 2015 suggests that the sustained, rapid reduction in malaria incidence observed between August 2010 and July 2014 has plateaued. This is not an unexpected finding as the decreasing trend evident until that point was unsustainable at the same trajectory. Sooner or later the rapidly decelerating incidence rate was destined to flatten out as the existing suite of malaria control interventions, delivered via current mechanisms and at current intensity, approached their maximum impact potential. It would appear that the program may now be reaching that 'maximum impact' point and more intensive intervention[1] may be necessary to achieve further substantive reductions in malaria incidence. Continued surveillance in the sentinel sites for at least a further 12-month period will be necessary before firm conclusions can be drawn in this regard, although the findings presented in this report could be considered an 'early warning' that the impact of current interventions (at current intensity) may be beginning to wane.

Secondly, the site-specific data highlight the considerable intra- and inter-site variation in crude malaria incidence, frequency of malaria cases and mRDT positivity rates reported over time. The overall trajectory of decreasing clinical incidence was not uniformly experienced at all sites. In some sites, such as Karimui the clinical incidence of malaria decreased substantially in late 2011 and has remained at low levels ever since. However, it could be argued that in that particular site, malaria incidence was unusually high at the time of starting surveillance. In other sites, such as Sausi and Lemakot, clinical incidence has fluctuated markedly over time and rapid, steep upward trends have been evident at certain time points. In yet other sites, such as East Cape, a relatively consistent decrease at a more gradual trajectory is observed. The inter- and intra-site variability is suggestive of differing impacts of LLIN distribution in the respective catchment populations of each sentinel site. The Karimui data indicate an immediate and sustained impact following the initial LLIN distribution whereas a number of other sites, such as Arawa, Balimo, Dreikikir and Lemakot indicate a marked reduction in malaria cases or clinical incidence following the initial distribution, but a rapid resurgence at approximately two years post-distribution. Sustained reductions in malaria cases or clinical incidence in these sites does not appear to have been achieved until after the second LLIN distribution. In Sausi it remains unclear whether a sustained reduction has been achieved even after the third LLIN distribution. These trends highlight the apparent

[1] 'Intensification' may include additional resource or effort to derive further benefit from existing malaria control interventions (e.g. campaigns to foster greater use of available LLIN) and/or the adoption of alternative or complementary malaria control interventions.

fragility of LLIN impact in some communities in PNG and suggest that rapid increases in incidence can and do occur despite multiple LLIN distributions based on the current three year replacement cycle.

Two further conclusions that may be drawn from the site-specific data are: 1) that the current suite of malaria control interventions, which targets indoor mosquito biting, misses a large part of malaria transmission in PNG (i.e. transmission driven by outdoor biting); and 2) relaxation of the current malaria control program would likely result in a rapid and marked increase in malaria cases in many PNG communities.

The data presented in this report are limited to seven sites and should not be considered representative of malaria epidemiology at a national, regional or even provincial level. Nevertheless, although few in number, the sites were purposely selected to provide localised data from diverse communities within each region of PNG and are likely to reflect the range of experience common across communities in PNG. The standard of data collection and reporting in the seven sites also follows a routine and rigorous protocol and may be considered a 'gold standard' in the PNG context.

Improved surveillance has been identified as one of three central pillars of the Global Technical Strategy for Malaria 2016–2030 [7]. Investing in routine information systems such as the NHIS is considered essential. This requires building operational and management capacity at all levels as well as expertise in monitoring, analysing and interpreting the collected data and the data quality. It has to be understood that surveillance systems serve slightly different functions as the malaria epidemiology changes (i.e. case numbers decrease) and should therefore be amenable to adaptation when required; but in any given situation, surveillance must be linked to response, data must be actionable. This requires a clear strategy and capacity for stratification and targeted implementation of control (and potentially elimination) measures.

As more data is required for decision making, there is a danger that existing reporting systems are over-loaded with increasing requests for information. Including an increasing number of variables in the NHIS may over-burden health workers who are required to invest time to provide the information next to their clinical duties. A thorough assessment of which indicators are really crucial for decision making at program level and limiting routine data

collection to a minimal set of essential indicators would therefore be advisable. Requesting health workers to collect and report data which may in the end never be utilised must be considered counter-productive. Detailed information to complement the basic NHIS indicators may be collected more adequately from a selected number of sentinel sites. In the case of malaria, this might include a detailed age and sex breakdown of clinical cases, as well as the species composition as diagnosed by microscopy or molecular methods. The PNGIMR malaria sentinel sites which are by now well established may serve the NMCP in this role of providing key indicators to complement the NHIS. Supporting sentinel sites alongside strengthening of the NHIS can be expected to provide the NMCP with the necessary data required for making programmatic decisions in the context of a declining, but highly heterogeneous malaria burden in PNG.

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Appendix A. Sentinel Surveillance Crude Malaria Rate Data, 2010-2015

		MONTHS											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
EAST CAPE													
2010	**No. Screened**							104	160	186	181	312	161
	No. RDT +							44	71	135	127	170	104
	Days screened							18	28	29	28	29	18
	RDT positivity							42%	44%	73%	70%	54%	65%
2011	**No. Screened**	245	243	195	143	173	106	75	90	68	105	78	59
	No. RDT +	143	141	120	68	59	19	26	25	11	19	23	31
	Days screened	24	24	26	24	27	18	21	26	25	26	20	20
	RDT positivity	58%	58%	62%	48%	34%	18%	35%	28%	16%	18%	29%	53%
2012	**No. Screened**	170	245	177	199	287	191	88	120	151	164	107	83
	No. RDT +	91	150	119	94	210	115	43	54	66	43	27	25
	Days screened	25	25	27	22	27	26	17	26	24	27	26	16
	RDT positivity	54%	61%	67%	47%	73%	60%	49%	45%	44%	26%	25%	30%
2013	**No. Screened**	212	197	205	326	304	129	127	74	57	49	93	17
	No. RDT +	106	106	127	106	126	78	51	17	17	8	28	4
	Days screened	24	24	24	25	27	24	25	23	25	15	25	7
	RDT positivity	50%	54%	62%	63%	41%	60%	40%	23%	30%	16%	30%	24%
2014	**No. Screened**	164	126	118	63	81	74	40	36	79	38	41	14
	No. RDT +	78	33	62	24	29	22	9	10	6	5	12	3
	Days screened	20	20	21	20	22	19	21	20	21	22	20	16
	RDT positivity	48%	26%	53%	38%	36%	30%	23%	28%	8%	13%	29%	21%
2015	**No. Screened**	81	104	116	138	83	64	32					
	No. RDT +	29	37	46	51	27	30	10					
	Days screened	20	20	23	18	18	21	19					
	RDT positivity	36%	36%	40%	37%	33%	47%	31%					
KARIMUI													
2010	**No. Screened**											221	
	No. RDT +											163	
	Days screened											7	
	RDT positivity											74%	
2011	**No. Screened**		104	79	166	112	95	68	48	46	45	38	25
	No. RDT +		55	39	67	38	37	28	9	9	6	6	1
	Days screened		10	8	19	19	20	16	22	20	20	22	22
	RDT positivity		53%	49%	40%	34%	39%	41%	19%	20%	13%	16%	4%
2012	**No. Screened**	23			61	103	22		34	113	142	129	
	No. RDT +	2			3	5	0		0	16	10	10	
	Days screened	22			19	31	10		10	28	31	29	
	RDT positivity	9%			5%	5%	0%		0%	14%	7%	8%	
2013	**No. Screened**	89	60	122	170	46	61	63	42				50
	No. RDT +	14	2	13	14	3	1	3	2				3
	Days screened	19	18	25	26	14	24	28	25				15
	RDT positivity	16%	3%	11%	8%	7%	2%	5%	5%				6%
2014	**No. Screened**	99	82	126	48	52	67	46	54	47	52	45	24
	No. RDT +	1	0	0	1	0	0	1	0	2	0	1	0
	Days screened	27	21	20	17	21	21	20	22	22	22	20	10
	RDT positivity	1%	0%	0%	2%	0%	0%	2%	0%	4%	0%	2%	0%
2015	**No. Screened**		66	80	58	30	36	38					
	No. RDT +		1	0	0	0	0	0					
	Days screened		20	24	22	16	17	17					

	RDT positivity		2%	0%	0%	0%	0%	0%					
		MONTHS											
		JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
SAUSI													
2010	**No. Screened**								4	135	112	85	167
	No. RDT +								1	30	23	16	34
	Days screened								1	21	18	13	20
	RDT positivity								25%	22%	21%	19%	20%
2011	**No. Screened**	231	164	246	152	137	79	96	87	53	113	78	76
	No. RDT +	81	67	82	43	37	20	21	17	7	19	18	5
	Days screened	23	18	23	17	20	14	20	18	21	21	20	14
	RDT positivity	35%	41%	33%	28%	27%	25%	22%	20%	13%	17%	23%	7%
2012	**No. Screened**	174	188	164	264	137	118	135	198	130	183	155	132
	No. RDT +	41	45	43	86	26	26	27	63	29	33	27	20
	Days screened	21	21	21	19	15	20	15	20	18	20	21	13
	RDT positivity	24%	24%	26%	33%	19%	22%	20%	32%	22%	18%	17%	15%
2013	**No. Screened**		150	116	88	113	114	40	134	72	144	90	40
	No. RDT +		25	14	12	9	17	12	34	20	22	45	16
	Days screened		17	17	20	19	14	6	18	10	23	14	6
	RDT positivity		17%	12%	14%	8%	15%	30%	25%	28%	15%	50%	40%
2014	**No. Screened**	50	139	111	59	56	182	110	196		187	117	94
	No. RDT +	12	52	26	14	15	72	37	55		66	42	47
	Days screened	10	20	16	12	13	19	10	17		19	10	9
	RDT positivity	24%	37%	23%	24%	27%	40%	34%	28%		35%	36%	50%
2015	**No. Screened**		194	113	84	119	55	64					
	No. RDT +		50	36	42	55	12	17					
	Days screened		15	8	9	15	13	17					
	RDT positivity		26%	32%	50%	46%	22%	27%					
LEMAKOT													
2010	**No. Screened**												
	No. RDT +												
	Days screened												
	RDT positivity												
2011	**No. Screened**	194	354	326	368	577	331	223	266	202	104	200	185
	No. RDT +	56	113	103	160	193	149	87	66	37	23	63	55
	Days screened	20	24	25	22	21	19	21	22	21	11	22	20
	RDT positivity	29%	32%	32%	43%	33%	45%	39%	25%	18%	22%	32%	30%
2012	**No. Screened**	180	256	300	145	520	300	221	269	245	199	280	121
	No. RDT +	67	143	195	98	402	250	182	256	146	145	48	49
	Days screened	20	21	22	15	22	17	14	22	19	12	22	15
	RDT positivity	37%	56%	65%	68%	77%	83%	82%	95%	60%	73%	17%	40%
2013	**No. Screened**	181	232	246	278	274	204	143	139	111	68	109	52
	No. RDT +	75	146	56	74	75	44	37	36	21	8	19	13
	Days screened	19	18	20	20	16	19	19	19	19	13	19	15
	RDT positivity	41%	63%	23%	27%	27%	22%	26%	26%	19%	12%	17%	25%
2014	**No. Screened**	135	102	96	91	89	178	148	84	53	102	24	57
	No. RDT +	22	40	23	18	16	19	20	21	9	29	2	12
	Days screened	18	19	20	21	22	20	20	20	19	23	9	16
	RDT positivity	16%	39%	24%	20%	18%	11%	14%	25%	17%	28%	8%	21%
2015	**No. Screened**	87	86	68	75	62	62	50					
	No. RDT +	24	25	11	10	14	12	9					
	Days screened	20	19	23	17	17	20	20					
	RDT positivity	28%	29%	16%	13%	23%	19%	18%					

		MONTHS											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
ARAWA													
2010	**No. Screened**												
	No. RDT +												
	Days screened												
	RDT positivity												
2011	**No. Screened**					125	182	89	122	51	71	43	39
	No. RDT +					3	6	6	7	1	1	0	0
	Days screened					16	19	19	21	18	20	21	17
	RDT positivity					2%	3%	7%	6%	2%	1%	0%	0%
2012	**No. Screened**	60	33	76	55	57	104	96	116	103	61	32	
	No. RDT +	4	2	13	10	13	24	18	33	6	23	6	
	Days screened	19	11	19	20	23	19	18	25	16	15	3	
	RDT positivity	7%	6%	17%	18%	23%	23%	19%	28%	6%	38%	19%	
2013	**No. Screened**		141	164	169	171	152	100	111	92	86	65	47
	No. RDT +		22	47	33	43	27	14	9	8	9	1	3
	Days screened		14	20	20	19	19	17	18	16	22	14	10
	RDT positivity		16%	29%	20%	25%	18%	14%	8%	9%	10%	2%	6%
2014	**No. Screened**				32	29	24	18	49	56	75	40	31
	No. RDT +				16	10	3	1	2	2	0	2	0
	Days screened				15	18	20	15	20	17	23	20	15
	RDT positivity				50%	34%	13%	6%	4%	4%	0%	5%	0%
2015	**No. Screened**	41	24										
	No. RDT +	8	7										
	Days screened	20	16										
	RDT positivity	20%	29%										
BALIMO													
2010	**No. Screened**												
	No. RDT +												
	Days screened												
	RDT positivity												
2011	**No. Screened**							109	75	73	76	71	69
	No. RDT +							3	1	0	1	1	3
	Days screened							23	24	22	24	21	18
	RDT positivity							3%	1%	0%	1%	1%	4%
2012	**No. Screened**	31	58	80	53	63	35		19	33	51	47	29
	No. RDT +	0	1	3	1	1	1		3	2	2	3	0
	Days screened	19	20	21	18	17	19		14	17	21	22	15
	RDT positivity	0%	2%	4%	2%	2%	3%		16%	6%	4%	6%	0%
2013	**No. Screened**	86	60	122	170	46							12
	No. RDT +	15	2	13	14	3							0
	Days screened	19	18	26	26	14							4
	RDT positivity	17%	3%	11%	8%	7%							0%
2014	**No. Screened**	36	55	36	44	31	18	17	22	22		15	
	No. RDT +	0	0	0	0	0	0	0	0	0		0	
	Days screened	23	17	16	22	17	20	21	21	18		18	
	RDT positivity	0%	0%	0%	0%	0%	0%	0%	0%	0%		0%	
2015	**No. Screened**	26	34	29									
	No. RDT +	0	0	0									

	Days screened	20	18	18									
	RDT positivity	0%	0%	0%									
		MONTHS											
		JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
DREIKIKIR													
2010	**No. Screened**												
	No. RDT +												
	Days screened												
	RDT positivity												
2011	**No. Screened**							53	227	126	53	157	130
	No. RDT +							6	15	12	5	43	36
	Days screened							9	22	18	8	19	10
	RDT positivity							11%	7%	10%	9%	27%	28%
2012	**No. Screened**	183	135	122	107	142	213	45	39	147	223		
	No. RDT +	55	32	37	32	37	52	8	18	63	69		
	Days screened	18	16	19	21	19	19	10	7	19	21		
	RDT positivity	30%	24%	30%	30%	26%	24%	18%	46%	43%	31%		
2013	**No. Screened**	139	47			85	159	61	59	104			
	No. RDT +	39	10			15	9	7	4	8			
	Days screened	11	7			13	19	21	17	17			
	RDT positivity	28%	21%			18%	6%	11%	7%	8%			
2014	**No. Screened**	89	107	4	47	45	102	116	101	32	51	42	64
	No. RDT +	13	21	0	7	9	24	32	26	11	18	12	18
	Days screened	14	18	2	16	15	20	18	16	14	15	14	17
	RDT positivity	15%	20%	0%	15%	20%	24%	28%	26%	34%	35%	29%	28%
2015	**No. Screened**	62	41	33	27								
	No. RDT +	10	12	3	5								
	Days screened	19	14	22	16								
	RDT positivity	16%	29%	9%	19%								

Appendix B. Crude Malaria Incidence Rate by Year (Aug – Jul) per Site

Site	**Crude Malaria Incidence Rate**(RDT + cases/1000 person years)*				
	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
Southern – East Cape	251	204	184	80	62
Highlands - Karimui	186	9	13	2	1
Momase - Sausi	154	109	93	137	200
Islands - Lemakot	199	238	153	32	22
TOTAL	**205**	**153**	**109**	**48**	**43**

*All calculations completed for a 12-month period between August of the first year and July of the second.