PAPUA NEW GUINEA INSTITUTE OF MEDICAL RESEARCH

PAPUA NEW GUINEA/THE GLOBAL FUND ROUND 3 MALARIA CONTROL PROGRAMME EVALUATION 2008/2009

RESULTS FROM CROSS-SECTIONAL SURVEYS AND SENTINEL SITES

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**V.2.1 includes corrections of typographical errors (pp 22, 23, 31, 34, 39).*

EXECUTIVE SUMMARY

Between 2004 and 2009, the malaria control programme in Papua New Guinea (PNG) was supported by the Global Fund to Fight AIDS, Tuberculosis and Malaria (GFATM) through the Round 3 malaria grant. The key interventions of the programme included the free distribution of long-lasting insecticide treated nets (LLIN) and the scaling-up of malaria diagnosis in health facilities, by improving microscopy and introducing rapid diagnostic tests (RDT). The key targets of the programme were 80% household ownership of LLINs and 80% usage among children under five years of age and pregnant women.

To evaluate the GFATM supported programme the Papua New Guinea Institute of Medical Research (PNG IMR) conducted cross-sectional surveys in households and health facilities across the country and evaluated data from seven Sentinel Sites.

Household surveys in randomly sampled villages across PNG revealed that in districts covered by the large-scale LLIN distribution campaign, 64.6% of the households owned an LLIN and 80.1% owned any type of net. In areas not covered by the campaign, only 8.1% owned an LLIN. In 43.8% of the post-intervention villages, the defined target of 80% ownership was achieved. 37.2% of the LLINs distributed in 2005 were still intact in 2008/09.

In the target group of children under five years of age, 39.5% slept under an LLIN the previous night, while 41.3% of pregnant women did so. Overall LLIN usage amounted to 32.5%. Usage of any type of net was slightly higher. In areas not yet covered by the distribution campaign, the percentage of people using LLINs was significantly lower; however, a similar proportion of the people slept under any type of net. Often, available nets were not used because they were either spared for later use or considered expired (i.e. damaged or too dirty).

Overall, 18.2% of blood samples collected from areas below 1600 meters altitude were positive for *Plasmodium* parasites. However, considerable regional variations in prevalence and species

KEY RESULTS

- Percentage of households owning LLIN: **64.6%**
- Percentage of children <5 years sleeping under LLIN: **39.5%**
- Percentage of pregnant women sleeping under LLIN: **41.3%**
- Parasitaemia in children <5 years
  Southern: **16.7%**
  Highlands <1600m: **20.0%**
  Momase: **21.7%**
  Islands: **32.3%**
- Percentage of febrile children <5 years treated with recommended first line antimalarials (CQ+SP or AQ+SP): **10.0%**
- Percentage of febrile health facility patients diagnosed with malaria: **3.6-76.7%**
- Monthly incidence of RDT-confirmed malaria in Sentinel Sites: **3-190 cases**
- Percentage of health centres with RDT in stock: **41.5%**
- Percentage of health centres with recommended first line antimalarials in stock: **90.2%**

composition were apparent. The highest burden was registered in Momase and Islands regions. Parasitaemia in children under five years of age ranged between 16.7% in Southern region and 32.3% in the Islands. Across all age groups, *P. falciparum* was the most frequently found parasite. However, in the Islands region, which showed the highest overall level of parasitaemia (25.1%), *P. vivax* was more prevalent than *P. falciparum* in all age groups. People living in villages with high mosquito net usage were significantly less likely to be infected with malaria parasites than those in villages with low net usage.

The majority of fever cases in the community were never brought to a health facility; however, over 55% of the cases took a drug to treat their fever. 38.8% reported to have used an antimalarial, but only 11.3% the recommended combination of chloroquine and sulphadoxine-pyrimethamine (SP) or amodiaquine and SP. In children under five years of age, administration of antimalarials in general (37.3%), and of the recommended regimen in particular (10%) were slightly below the treatment rates in the age group 5-14 years.

Baseline data from Sentinel Site health facilities confirmed the assumption that many cases of febrile illness are not due to malaria. The proportion of RDT-positive patients among all patients attending the outpatient clinics with a history of recent fever varied between 76.7% in East Sepik, to around 40-50% in sites in Madang and Morobe, to less than 4% in a site in Western province. The corresponding monthly malaria incidence varied between 3 and 190 RDT-confirmed cases.

These results underline the importance of appropriate parasitological diagnosis at the level of the health facility. None of the visited aid posts and only about half of the health centres had any diagnostic tools available. Even the recommended antimalarial treatment regimen was only available in 44.4% of the aid posts. Considering that aid posts are often the most easily accessible source of care and 17% of recent fever cases in these studies sought care from aid posts, their service provision urgently needs to be improved.

In conclusion, the targets of reaching 80% ownership and usage of LLINs were not reached despite a significant increase in mosquito net ownership over the course of the campaign. Operational challenges, including limited planning capacities at provincial and district levels, problems in accessing remote locations, tribal conflicts, as well as lack of awareness of the benefits of regularly using mosquito nets contributed to insufficient ownership and usage. Data from prevalence surveys supported previous findings of major differences in malaria endemicity between and within geographical regions. The Islands, followed by Momase, recorded the highest malaria burden. Conversely, mosquito net usage was lowest in the Islands. A major initiative addressing mosquito net usage in the Islands as well as all other regions is required in order to reach the Round 8 targets and achieve an improvement in the malaria situation. At the same time, planning and implementation capacity needs to be improved at national, provincial and district levels. All malaria control programme interventions should be integrated into routine preventive health services in order to make maximum use of limited financial and human resources. For mosquito nets, this includes exploring new sustainable distribution channels that guarantee continuous supply of nets even to remote areas.

On the treatment side, fever cases are rarely treated according to national malaria treatment guidelines. While the proportion of malaria among fever episodes presented to health facilities varied greatly between regions, even in areas with a high malaria-attributable fraction treatment with one of the recommended antimalarial combinations was rare. The availability of diagnostic tools and antimalarial drugs was not satisfactory in many facilities, particularly at the level of aid posts.

While the ownership of LLINs has improved over Round 3, a considerable investment in all other areas of malaria control is required. This includes a serious investment to improve the national health system in order to bring prompt and appropriate diagnosis and treatment to the people affected by malaria. Training, advocacy and behaviour change messages will be required to ensure that preventive and curative measures are fully utilised. Results from ongoing evaluation activities as well as operational research should thereby provide the evidence for programme implementation and policy decisions.

CONTENTS

ABBREVIATIONS

ACT	Artemisinin-based Combination Therapy
AP	Aid Post
CI	Confidence Interval
DHS	Demographic and Health Survey
EBC	Evangelical Brotherhood Church
G6PD	Glocose-6-Phosphate Dehydrogenase
GFATM	The Global Fund to Fight AIDS, Tuberculosis and Malaria
GPS	Global Positioning System
HC	Health Centre
HMM	Home-based Management of Malaria
IRB	Institutional Review Board
ITN	Insecticide Treated Net
LLIN	Long-Lasting Insecticide Treated Net
MRAC	Medical Research Advisory Committee
NDoH	National Department of Health
NGO	Non-Governmental Organization
OR	Odds Ratio
Pf	*Plasmodium falciparum*
PNG	Papua New Guinea
PNG IMR	Papua New Guinea Institute of Medical Research
Pv	*Plasmodium vivax*
RAM	Rotary Against Malaria
RDT	Rapid Diagnostic Test
SC	Sub-Health Centre
SP	Sulphadoxine-Pyrimethamine
WHO	World Health Organization


MOSQUITO
SPRAYS
COILS
BED NET
FISH

1 INTRODUCTION

Malaria is one of the principal health problems in Papua New Guinea (PNG). The disease is highly endemic in all lowland areas of the country while the highlands are prone to epidemics (1). In 2008, 1.6 million cases of malaria (approx. 244 cases per 1000 population) and 628 malaria deaths (approx. 10 per 100,000 population) were reported (2).

The Global Fund to Fight AIDS, Tuberculosis and Malaria (GFATM) Round 3 malaria grant supported the Papua New Guinea Malaria Control Program from 2004 to 2009 by financing the nationwide free distribution of long-lasting insecticide treated nets (LLIN) and the scaling-up of malaria diagnosis in health facilities, by improving microscopy and introducing rapid diagnostic tests (RDT).

Insecticide-treated nets (ITN) have become the primary tool for preventing malaria infection and transmission worldwide. Their effectiveness and impact on morbidity and mortality have been demonstrated in trials and studies in every type of malaria setting worldwide, including PNG (3;4). LLINs are pre-treated ITNs with the insecticide incorporated into or bound around the net fibres. Re-treatment, which has always been a major obstacle to the effectiveness of conventional ITNs, is therefore not required. Used correctly, LLINs retain their biological activity for three to five years.

Large-scale free distribution of LLINs in PNG started in 2005 with funds from the GFATM Round 3 malaria grant.[1] The PermaNet brand of LLINs (manufactured by Vestergaard Frandsen) was chosen for large scale distribution throughout PNG. Nets were imported by Rotary Against Malaria (RAM), a non-profit organization committed to fighting malaria in PNG, and delivered to provincial or district headquarters. The local distribution was then organised by the provincial and district health authorities. The number of nets to be handed out per household was calculated based on the 2000 population census, an average annual growth rate and a distribution ratio of one net per 2.5 household members. The LLINs were delivered in three different sizes: single nets, double nets or family size. Anecdotal evidence suggested that in practice, the number of nets delivered to the districts, the different net sizes and the ratio of 2.5 often posed a challenge to the distribution teams.

In order to evaluate the outcome and impact of the GFATM funded malaria control interventions, the NDoH contracted the Papua New Guinea Institute of Medical Research (PNG IMR) to develop and implement an evaluation plan. Funding for this evaluation was transferred to PNG IMR on 8th August 2008 and evaluation activities started immediately. The evaluation was conducted country-wide in the years 2008-2009.

[1] Smaller-scale distributions (usually of ITNs or non-treated nets) had previously been conducted only in selected areas by non-governmental organizations (NGOs), provincial or district governments, or other entities.

2 INDICATORS

Based on the evaluation plan developed by PNG IMR and NDoH three **key outcome indicators** related to free distribution of LLINs were defined in the GFATM grant agreement (Table 2-1). The indicators were assessed against the year 5 (2009) targets in districts in which the large-scale free LLIN distribution campaign had been implemented.

Table 2-1: GFATM mosquito net indicators

Outcome Indicator	Year 1 2005	Year 2 2006	Year 3 2007	Year 4 2008	Year 5 2009
Percentage of households owning at least one LLIN	9%	25%	45%	65%	**80%**
Percentage of children under 5 sleeping under a LLIN the previous night	10%	30%	50%	75%	**80%**
Percentage of pregnant women sleeping under a LLIN the previous night	2%	5%	50%	75%	**80%**

Additional information on mosquito net ownership and usage was collected to elucidate regional differences and reasons for non-ownership and for non-usage of nets.

For impact evaluation, a set of **impact indicators** were defined based on data collection in Sentinel Sites. No targets had been defined for these indicators in the Round 3 grant agreement. Due to the late arrival of funds, only baseline data has been collected for these indicators. Follow-up data will be collected as part of the Round 8 evaluation plan. The following impact indicators assessed through health facility outpatient monitoring will be presented in this report:

1. Percentage of febrile patients with RDT confirmed malaria
2. Monthly RDT confirmed incidence of malaria

Additional indicators were defined in the PNG IMR evaluation plan which can assist tracking programme outcome. These included the following health facility level indicators:

1. Percentage of health facilities with working microscopy
2. Percentage of health facilities with RDTs in stock
3. Percentage of health facilities with first-line antimalarials in stock

3 METHODOLOGY

3.1 Study design: household survey

A **cross-sectional household survey** was designed to collect household and individual level data on key outcome indicators listed in Table 2-1 from across PNG. The survey was carried out once between October 2008 and August 2009, i.e. after the implementation of the GFATM supported programme in large parts of the country. Indicators were assessed against the final target (year 5 of Round 3 Grant) and only included locations already covered with the GFATM supported programme between 2005 and 2007 (years 1 to 3 of Round 3 Grant).

Due to the late start of the evaluation, it was not possible to collect pre-intervention data for a before-after assessment to define representative contemporary control groups. Pre-intervention data on LLIN coverage, usage and parasite prevalence collected in seven Sentinel Sites may help contextualize the main results. However, these sites were purposively identified and are not necessarily comparable with the randomly sampled locations. Sentinel Sites are described in more detail in the following section.

The household survey included interviews with household heads, collection of finger-prick blood samples from household members and collection of LLIN samples. In addition, a short interview with staff of the nearest health facility collected basic health facility level information.

Selection of study households was based on a stratified multi-stage random sampling procedure. Existing political structures (province, district, and village) were used as sampling stages. At every stage, equal numbers of sampling units were selected. Final sampling units were households within which all individuals were included.

Seventeen out of the total of 20 provinces were eligible for outcome evaluation. In each province, two districts previously covered with the LLIN campaign were randomly selected. In two provinces, only one district was eligible for selection. In each district, two villages were randomly sampled from a geo-referenced list of villages. Simultaneously, basic health facility level data was collected from the health centre closest to each village. Due to financial and time constraints, locations which were extraordinarily difficult to reach (e.g. by hiring a helicopter or walking for more than one day) were replaced by another randomly sampled village. The random number list generator of Epi Info 6 (Centres for Disease Control and Prevention and World Health Organization) was used for all random sampling procedures on these levels.

In each study village, 30 households were randomly sampled upon arrival. The samples were drawn from household lists which were established by the village leaders and the survey

teams. For individual level data, including blood sample collection, all members of the sampled households were eligible.

3.1.1 Data collection procedures

Interviews with the household head represented the central part of the survey. Prerequisite for the interview was the presence of the household head during the time of the survey (usually two days per village) and the verbal consent to participate. Using a structured questionnaire, the interview collected information on ownership and usage of mosquito nets and on recent febrile illness episodes in the household. Demographic characteristics of all household members were also recorded. Accounts on mosquito net ownership were usually verified by the field interviewers who checked the presence of the nets and the net types (LLIN or other net).

In selected villages of malaria endemic areas, finger-prick blood samples were collected from all available and consenting members of the sampled households. Blood samples were collected as thick and thin smears on glass slides for microscopic examination and on filter papers for molecular diagnostics. At the same time, haemoglobin levels were measured with a portable HemoCue Hb 201+ Analyser (HemoCue AB, Ängelholm, Sweden). An RDT (ICT Diagnostics, Cape Town, South Africa) was performed for on-the-spot diagnosis if a household member suffered from fever at the time of the interview. Blood sample collection was accompanied by the administration of a short questionnaire eliciting information on previous malaria treatment and recent travel.

In each village, GPS coordinates, accessibility, and other progress monitoring data were recorded. During a visit to the nearest health centre, a structured questionnaire was used to elicit information on staffing, drug stock, diagnostic capacity, and patient numbers in the previous month.

Interviews and blood collection were done by two teams of PNG IMR field workers trained in the research methodology. Each team was led by a staff member with extensive experience in malaria field research and also included two nursing officers. Participation in the interviews and collection of blood samples was voluntary and decisions not to participate were respected. Household members who refused to give blood were only administered the accompanying questionnaire.

3.2 Study design: Sentinel Sites

Seven Sentinel Sites were established in purposively selected locations to monitor developments in morbidity and mortality indicators alongside changes in interventions coverage. Selection of the sites was based on operational and epidemiological considerations. Contrary to locations for outcome surveys, only places with net distribution

after year 3 of Round 3 were considered. In addition, endemic malaria, a functioning and collaborative health centre, and reasonable accessibility were prerequisites for selection. Sentinel Sites were defined as consisting of a health centre and the villages in its catchment area.

In each Sentinel Site, a baseline household survey was carried out in three villages prior to the LLIN distribution campaign. The survey villages were selected randomly from within a 5 to 10 km radius around the health centre. The methodology of the survey was identical with the outcome surveys and included interviews with household heads and collection of finger-prick blood samples from household members.

In 5 out of the 7 Sentinel Sites, the incidence of malaria cases was monitored over a period of two months during the main malaria transmission season. All patients attending the outpatient clinics were screened and blood samples collected from those with a history of recent fever. An RDT was performed on the spot by a PNG IMR nursing officer based at the health centre. Demographic and malaria-related information was collected from all fever patients. The data allowed the calculation of crude malaria incidences and malaria attributable fractions. Incidence rates were not calculated due to the unreliability of the catchment population data available from the health centres.

These Sentinel Site activities will be repeated after one year to assess changes in malaria and coverage indicators after the implementation of the LLIN distribution campaign in these locations.

3.3 Study design: health facility data

During household surveys in post-distribution villages and Sentinel Sites, the health facility nearest to the survey village was identified and visited by the survey team. The health facilities were hence sampled indirectly as a function of the random sampling procedure applied for the villages (as described above). A structured questionnaire administered to the officer-in-charge served to collect data on staffing, diagnostic capacity, and availability of antimalarials. In situations in which more than one survey village shared the same nearest health facility, the facility was included only once in the analysis. A list of surveyed health facilities can be found in Appendix 3.

3.4 Diagnostic procedures with blood samples

Blood slides for light microscopy were prepared with thick and thin smears on the same slide. The slides were read in the microscopy sections at PNG IMR in Goroka and Madang.

Each slide was read twice by two different microscopists. Confirmatory reads were performed by a senior microscopist in case of discordant results.

The RDTs used in Sentinel Sites and during village clinics were ICT Malaria Combo Cassette Tests manufactured by ICT Diagnostics. In a recent summary report, the tests detected over 85% of wild type *P. falciparum* infections at a level of 200 parasites/µl and 100% at 2000 or 5000 parasites/µl. The test also detected 95% of wild type *P. vivax* samples at high density, however, it failed to detect *P. vivax* positive samples at 200 parasites/µl (5). Low-density *P. vivax* infections are therefore likely to remain undetected. Due to the target antigens (HRP2 and aldolase), the ICT Combo test allows distinguishing between three diagnostic categories: (1) *P. falciparum* infection, (2) non-*P. falciparum* infection, and (3) *P. falciparum* monoinfections or mixed infection with *P. falciparum* and other *Plasmodium* species. The tests were provided by NDoH.

3.5 Data analysis

All data were double-entered into a Microsoft FoxPro database at PNG IMR Goroka and analysed with Stata (StataCorp LP, College Station, USA) software.

For household and individual level indicators derived from outcome surveys, unweighted and weighted proportions were estimated using the survey design command set in Stata. The report presents aggregated national and regional level data as weighted proportions. Provincial and village level data in Appendix 4 are unweighted[2]. Overall weights were calculated as the inverse of an observation's probability of selection. To account for the staged sampling strategy, the overall probability of selection was calculated as a product of the selection probabilities at each sampling stage, i.e. the probability of a district being selected within a province; the probability of a village being selected within a district; the probability of a household being selected within a village. Since all individuals of the sampled household were eligible, individual level weights equalled the weights of the households to which an individual belonged. Sentinel Site data are presented without weights.

Bivariate analyses included chi-square tests to assess dichotomous variables, Mann-Whitney U-tests to compare non-normally distributed continuous data, and t-tests to compare normally distributed continuous data.

[2] The aim of this evaluation was to provide national level estimates. Provincial data in Appendix 4 is provided for reference purposes only. Due to the small sample size, provincial level estimates do not necessarily allow inferences to be made about the situation in the entire province.

3.6 Ethical clearance

The study protocol was approved by the Institutional Review Board of PNG IMR (IMR IRB No. 0803) and the Medical Research Advisory Committee (MRAC No. 07.30, 30th November 2007).


PermaNet
for people including babies

4 RESULTS: MOSQUITO NET COVERAGE

4.1 Characteristics of household survey sample

Household surveys were conducted in a total of 64 villages in 32 districts in 17 provinces (Figure 4-1). In two provinces, only one district was selected (Manus Province is only one district, Western Province had only one district covered with LLIN in 2008). In each district, two villages were visited with the exception of Angalimp-South Wahgi (Western Highlands Province) where three villages were visited in order to reach the required sample size.

Of all 64 outcome survey villages, 20 (31.3%) could be reached by road (highway, gravel, or bush road) either from Port Moresby or from Goroka. Another 44 villages (68.8%) required travel by air, ship or boat either to the provincial headquarters (23, i.e. 35.9%) or from the headquarters onwards (7, i.e. 10.9%) or both (14, i.e. 21.9%). Three villages could only be reached by foot.

Fifty (78.1%) villages were located below 1300 m altitude where climatic conditions are generally favourable for endemic malaria transmission (Figure 4-1). Another nine (14.1%) were located at altitudes of unstable transmission between 1300 and 1700 m where malaria endemics may occur and five (7.8%) villages were above 1700 m where malaria transmission is unlikely (1).

In total, 1958 households were visited and the household heads interviewed. Individual level usage data were collected for 10988 individuals, including 1652 children under five years of age (i.e. 15.1% of all individuals with reported age) and 136 pregnant women aged 15 to 49 years (i.e. 5.2% of all women in this age group) (Table 4-1). A detailed list of visited villages and number of interviews conducted can be found in Appendix 1.

Table 4-1: Number of household interviews and individual usage data by province

Province	Villages	Household interviews		Individuals	
		Number	Percent	Number	Percent
Western	2	53	2.7	407	3.7
Gulf	4	125	6.4	710	6.5
Central	4	123	6.3	858	7.8
Milne Bay*	3	90	4.6	418	3.8
Northern	4	137	7.0	873	8.0
Western Highlands	5	129	6.6	668	6.1
Chimbu	4	125	6.4	634	5.8
Eastern Highlands	4	132	6.7	590	5.4
Morobe	4	120	6.1	642	5.8
Madang	4	119	6.1	664	6.0
East Sepik	4	120	6.1	648	5.9
West Sepik	4	113	5.8	659	6.0
Manus	2	60	3.1	391	3.6
New Ireland	4	131	6.7	591	5.4
East New Britain	4	119	6.1	686	6.2
West New Britain	4	127	6.5	853	7.8
Bougainville	4	135	6. 9	696	6.3
Total	64	1958	100	10,988	100

*In Milne Bay Province, all questionnaires from a forth visited village (Onaneba on Kiriwina Island) were lost during air transport.

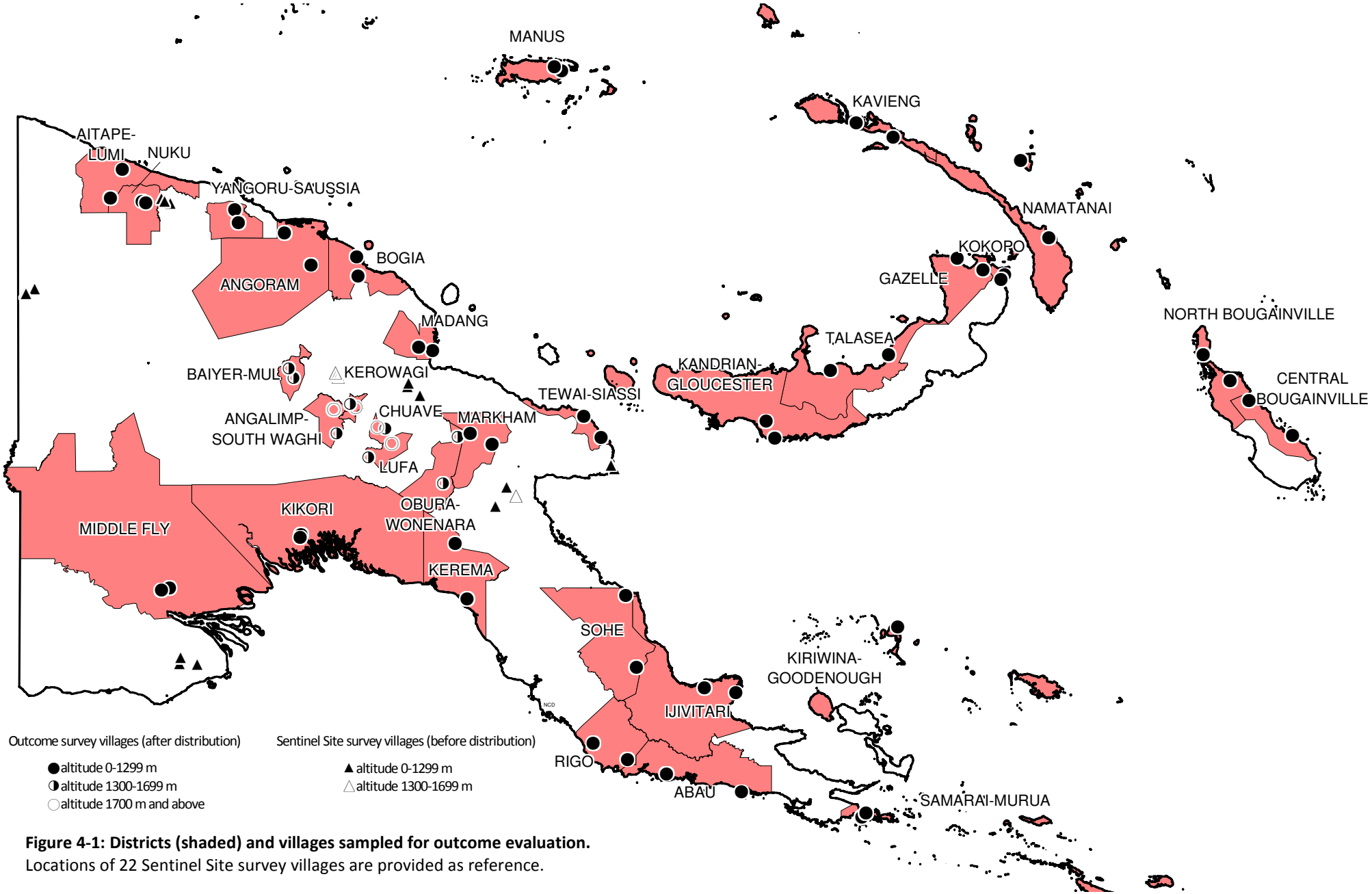


Figure 4-1: Districts (shaded) and villages sampled for outcome evaluation.
Locations of 22 Sentinel Site survey villages are provided as reference.

4.2 Mosquito net ownership

Base on the weighted analysis of household level data, a total of 64.6% (95% Confidence Interval [CI] 55.5-72.7) of the households owned at least one LLIN. Two or more LLINs were owned by 38.2% (31.3-45.7) of all households[3]. The average number of LLINs per household was 1.3 (1.1-1.5; including all surveyed households). Households with at least one LLIN owned on average 2 LLINs (1.8-2.2).

In most study villages, several households possessed mosquito nets that were obtained prior to the GFATM supported large-scale distribution of LLINs. Most of these nets were either conventional ITNs or untreated nets with only few LLINs that had been distributed in small-scale campaigns. The coverage with mosquito nets in general (including untreated, pre-treated or long-lasting insecticide treated nets) consequently exceeded the LLIN coverage. Overall, 80.1% (75.1-84.3) of all households owned at least one mosquito net of any type. The average number of nets per household was 1.8 (1.6-1.9). The key indicators of household net ownership are illustrated in Figure 4-2 and summarized in Table 4-4.

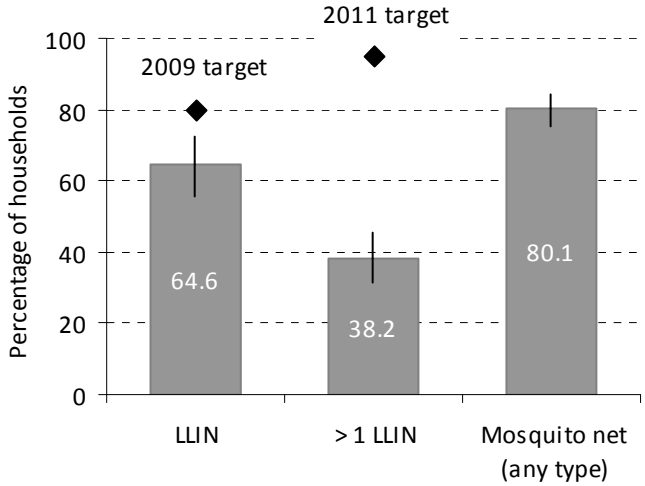


Figure 4-2: Household ownership of mosquito nets in Papua New Guinea.

Weighted proportions and 95% CI.

In comparison, out of 696 households in 22 villages of seven Sentinel Sites not yet covered with large-scale LLIN distribution, only 8.1% (3.9-16.0) owned an LLIN and 57.6% (47.6-67.1) a mosquito net of any type (Figure 4-3).

[3] Under the GFATM Round 8 Malaria Grant the "proportion of households with at least two LLINs" will be assessed as outcome indicator with a target of 95% ownership after year two and 98% in year five.

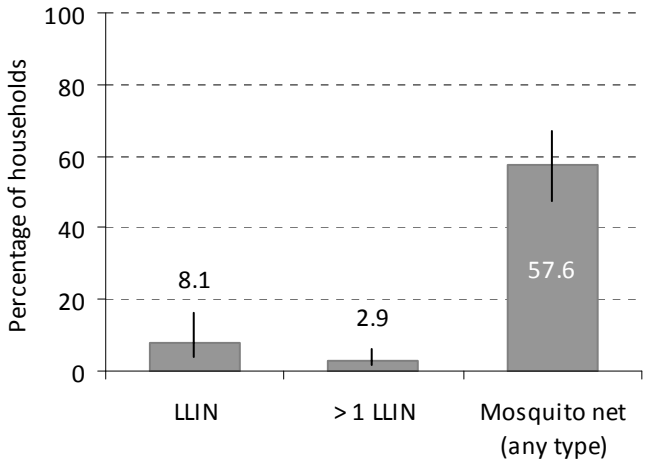


Figure 4-3: Household ownership of mosquito nets in seven Sentinel Sites prior to large-scale distribution.

Unweighted proportions and 95% CI.

Assessed against the Year 5 target of 80%, the household ownership of LLINs in districts already covered with large-scale free distribution has remained 15.4 percentage points below the target. Compared to pre-intervention areas, LLIN ownership was eight times (or 56.5 percentage points) higher in districts covered with the distribution campaign.

Out of all 64 villages surveyed after the distribution campaign, 28 (43.8%) had a household LLIN coverage of 80% and above (Figure 4-4). On the other hand, in three villages (4.7%) none of the approximately 30 visited households owned an LLIN. The seven villages (10.9%) with less than 10% LLIN coverage were located in seven different provinces, three of them in Southern Region, three in the Highlands, and one in Momase.

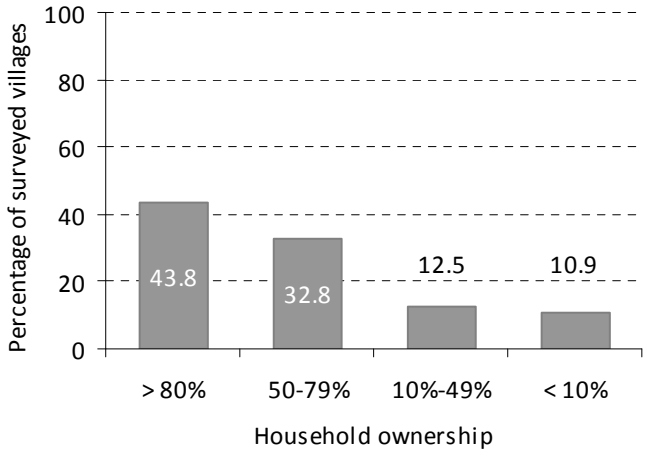


Figure 4-4: Household LLIN ownership levels by village.

4.2.1 Differences between Regions

Regional differences were observed in the ownership of mosquito nets in general and LLINs in particular (Table 4-4 and Figure 4-5). The highest LLIN ownership was found in the Islands Region (70.2%, 61.9-77.4), the lowest in the Highlands (56.3%, 37.2-73.7). However, these differences, though substantial (14 percentage points between Highlands and Islands), were not statistically significant. In no region was the target of 80% clearly reached.

The highest household ownership of mosquito nets of any type was found in Momase Region (95%, 88.5-97.9), the lowest in the Highlands (70.7%, 60.1-79.4). Regional differences in ownership of any type of net were statistically significant (P=0.003). In Momase, conventional ITNs and/or untreated nets contributed significantly to the overall net ownership, resulting in a lower level of LLIN ownership.

The highest average number of nets in general (2.2) and LLINs in particular (1.6) per household was recorded in Southern Region.

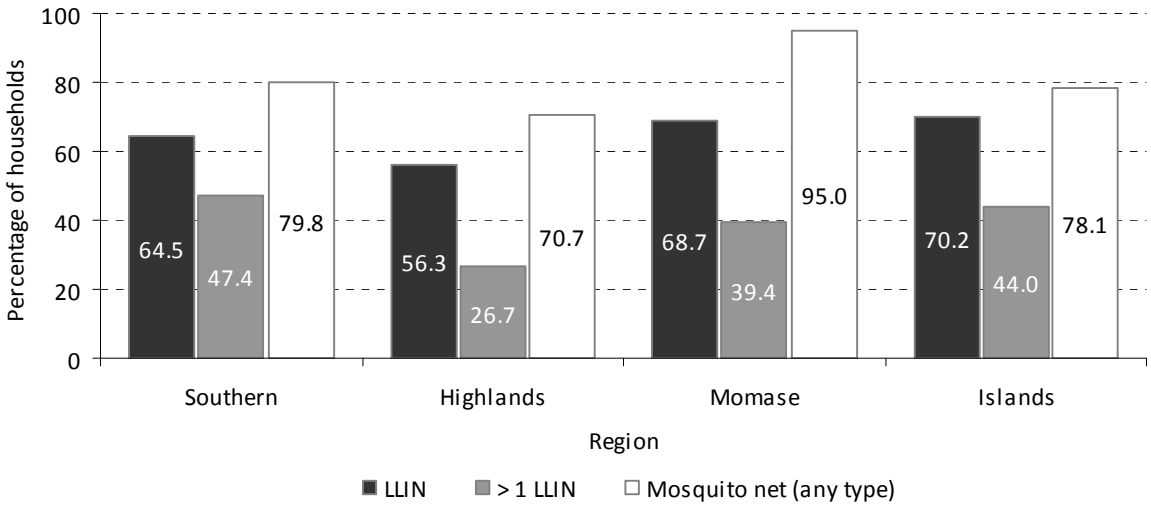


Figure 4-5: Household ownership of mosquito nets by region.

4.2.2 Differences between distribution years

Further differences were noted between villages covered by the distribution campaign in 2005, 2006 or 2007 and later. The grouping in distribution years was done according to information provided to PNG IMR by the Malaria Branch at NDoH (Appendix 2). The date of completing (rather than starting) the distribution was relevant for the grouping. Villages covered later in the distribution programme showed a higher household ownership in the 2008/2009 survey than those receiving LLINs in the first round in 2005. However, this association was also not statistically significant (Table 4-4). The study design did not allow establishing whether the differences in ownership observed during the survey were due to

the distribution itself or due to loss of nets over time. However, the ownership of non-LLINs did not show the same increasing trend as the LLIN ownership, suggesting that LLIN ownership may indeed be related to the effectiveness of the distribution round (Figure 4-6).

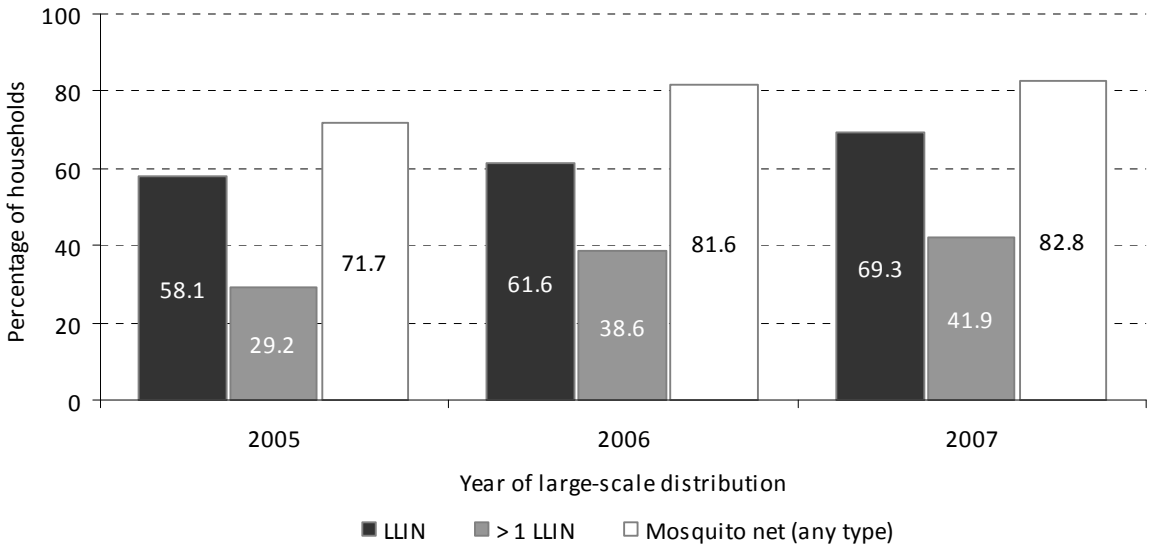


Figure 4-6: Household ownership of mosquito nets by year of distribution in the respective village

4.2.3 Physical condition of mosquito nets

A total of 3639 mosquito nets were recorded during the household interviews. For 3506 (96.4%) of these nets, information on their physical condition was recorded by interviewers who inspected the nets during the household visits. 1789 (51.0%) of the observed nets were still intact, the remaining had holes or were torn. 2635 (72.4%) observed nets were LLINs of which 1462 (56.0%) were still intact. Not surprisingly, LLINs distributed earlier in the campaign were significantly more likely to have holes than LLINs distributed the year before the survey. In villages that received nets in 2005, only 37.2% of the LLINs were intact three years after the distribution (Table 4-2).

Table 4-2: Condition of LLINs collected in 2008-09 by year of distribution

Year of distribution	Percentage of LLINs intact*	Total No. of LLINs
2005	37.2	465
2006	41.1	782
2007+	71.0	1364
Total	56.0	1462

* P<0.001

4.2.4 Reasons for not owning a mosquito net

Out of 314 households that did not own a mosquito net of any type, 203 (84.7%) reported that their household had been left out by the campaign or that they missed the distribution either because of temporary absence or because they moved to the village only after the distribution. 69 (22.0%) households reported their nets had been destroyed (Table 4-3).

Table 4-3: Reasons for not owning mosquito net

Reasons mentioned	Number of households	Percentage
No net issued/left out/missed distribution	203	64.6
Net was destroyed/discarded	69	22.0
Net given away/used elsewhere	10	23.2
Net was being sold/too expensive	4	1.3
Net stolen	9	2.9
Other reasons	19	6.1
Total households without nets	314	100

Interestingly, more households covered in the 2007 campaign round reported to have missed the distribution or to have been left out (75.2%) than in villages covered in 2006 (66.7%) or 2005 (52.5%). On the other hand, households covered in earlier campaign rounds were more likely to have discarded their destroyed nets by the time the survey was conducted. In Momase Region, 95.2% of the households without nets reported they were left out or missed the distribution, compared to 75.0% in the Highlands, 64.8% in Southern and 48.2% in the Islands Region.

Table 4-4: Key indicators of mosquito net ownership in Papua New Guinea (weighted analysis).

Background characteristics	Percentage of households with at least one net	Percentage of households with more than one net	Average number of nets per household	Percentage of households with at least one LLIN	Percentage of households with more than one LLIN	Average number of LLINs per household	Number of households
	% (95% CI)	% (95% CI)	No. (95% CI)	% (95% CI)	% (95% CI)	No. (95% CI)	
Region							
Southern	79.8 (63.0-90.2)	61.9 (49.6-72.8)	2.2 (1.9-2.6)	64.5 (42.4-81.7)	47.4 (30.9-64.5)	1.6 (1.1-2.2)	528
Highlands	70.7 (60.1-79.4)	38.5 (26.0-52.7)	1.3 (0.9-1.7)	56.3 (37.2-73.7)	26.7 (12.2-48.9)	1.0 (0.5-1.5)	386
Momase	95.0 (88.5-97.9)	69.7 (64.0-74.8)	2.0 (1.9-1.7)	68.7 (48.0-83.8)	39.4 (28.9-50.9)	1.2 (0.9-1.6)	472
Islands	78.1 (70.2-84.4)	51.6 (44.1-59.0)	1.7 (1.4-1.9)	70.2 (61.9-77.4)	44.0 (35.8-52.4)	1.4 (1.2-1.7)	572
P-value	**0.003***	**<0.001***	0.058§	0.539*	0.197*	**0.031**§	
Year of distribution							
2005	71.7 (57.5-82.6)	44.5 (32.2-57.5)	1.5 (1.1-1.8)	58.1 (45.0-70.1)	29.2 (22.0-37.5)	1.0 (0.8-1.2)	471
2006	81.6 (70.4-89.2)	56.4 (46.2-66.1)	1.8 (1.5-2.1)	61.6 (46.3-75.0)	38.6 (27.4-51.1)	1.2 (0.9-1.6)	622
2007 & later	82.8 (71.5-90.2)	55.9 (44.8-66.3)	1.9 (1.6-2.2)	69.3 (53.3-81.7)	41.9 (30.2-54.6)	1.4 (1.1-1.8)	865
P-value	0.343*	0.363*	0.012§	0.453*	0.273*	0.017§	
Total	80.1 (75.1-84.3)	53.7 (48.7-58.5)	1.8 1.6-1.9	64.6 (55.5-72.7)	38.2 (31.3-45.7)	1.3 (1.1-1.5)	1958

* Chi-square test § Linear regression

4.3 Usage of mosquito nets

Data on mosquito net usage were available for 10,257 individuals (93.3% of all recorded individuals), including 1599 children under five years of age (96.8% of all recorded children) and 132 (self-reported) pregnant women between 15 and 49 years of age (97.1% of all recorded pregnant women aged 15 to 49). A weighted analysis of mosquito net usage was performed for the target groups of children under five years of age, pregnant women, and the population as a whole. Key results of net usage are presented in Table 4-5.

Amongst children under five years of age, 39.5% (95% CI 32.8-46.5) had slept under an LLIN the previous night and 51.8% (45.4-58.1) under any type of mosquito net. Usage of LLINs by pregnant women was 41.3% (31.6-51.8) and 56.1% (44.1-67.5) slept under any type of net. Usage of nets was higher in those women reported pregnant than in non-pregnant women, however, this was not statistically significant for LLINs (P=0.115) nor for nets in general (P=0.068). Overall usage of LLINs by members of visited households amounted to 32.5% (27.0-38.4); usage of any type of nets was 44.3% (38.8-49.9) (Figure 4-7).

LLIN usage was significantly higher in children under five years of age compared to older age groups (Table 4-5) and it was higher in male than in female household members above 15 years of age (P<0.001). In children under five years of age, there were no differences in usage of LLINs or nets in general between the child's sex or age (in years) (Table 4-6).

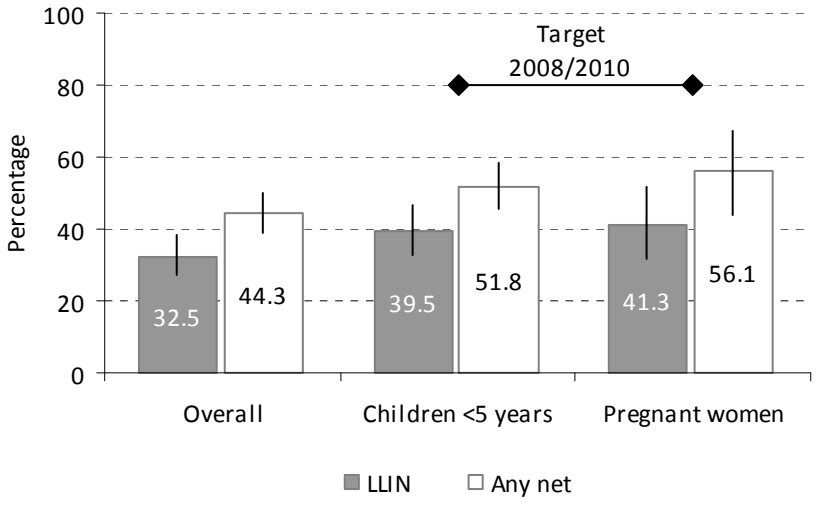


Figure 4-7: Mosquito net usage by target groups

Weighted proportions and 95% CI.

A comparison of these figures with the data collected from 3256 individuals in 22 villages of seven Sentinel Sites not yet covered with large-scale LLIN distribution reveals few differences in the use of mosquito nets in general. However, in villages covered by the

distribution about ten times more people used LLINs than in the Sentinel Site villages (Odds Ratio 10.3, P<0.001) (Figure 4-8).

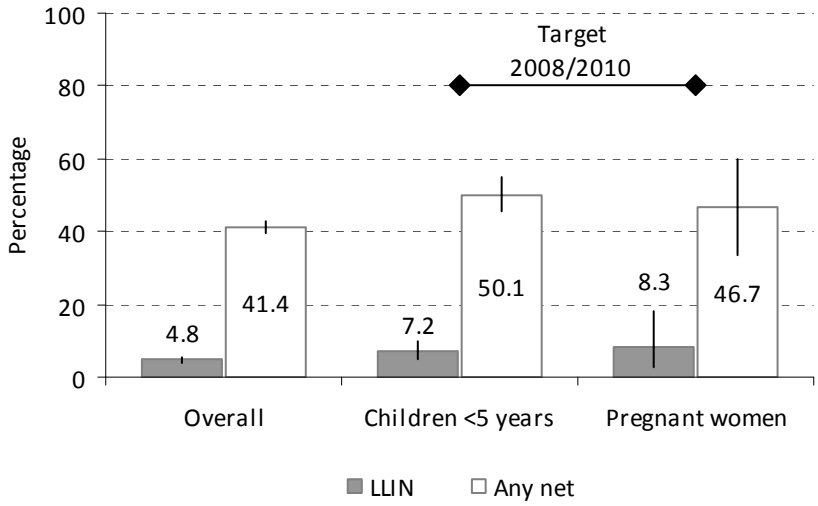


Figure 4-8: Mosquito net usage in Sentinel Sites.

Unweighted proportions and 95% CI.

4.3.1 Differences between Regions

Regional differences were observed in LLIN usage by the two target groups (children under five years of age and pregnant women) and by the general population. The highest usage was observed in Momase Region, the lowest in Highlands and Islands Regions (Figure 4-9). Differences were statistically significant for LLINs and for mosquito nets in general (Table 4-5).

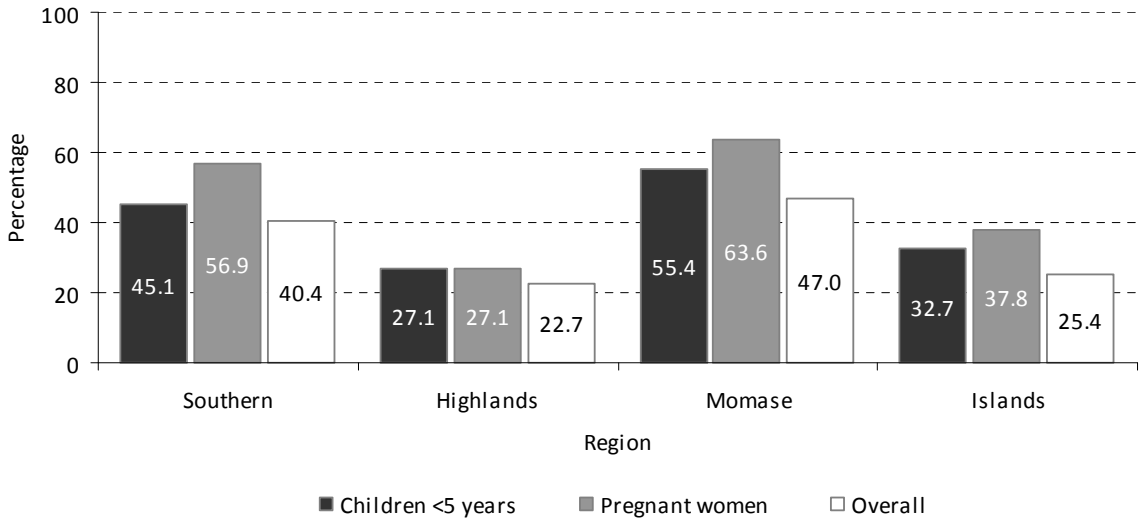


Figure 4-9: LLIN usage by region

Weighted proportions.

Generally, LLIN usage was much lower than ownership. This difference was most pronounced in the Islands where 70% of the surveyed households owned an LLIN, but only 33% of household members slept under an LLIN.

Table 4-5: Key indicators of mosquito net usage in the general population (weighted analysis)

Background characteristics	Percentage of household members who slept under a net last night	Percentage of household members who slept under an LLIN last night	Number of household members
	% (95% CI)	% (95% CI)	
Age (in years)			
<5	51.8 (45.4-58.1)	39.5 (32.8-46.5)	1599
5-14	43.2 (36.9-49.7)	30.9 (24.9-37.5)	2959
15+	42.8 (37.2-48.5)	31.3 (25.9-37.4)	5679
P-value*	**0.003**	**0.004**	
Sex			
M	42.3 (36.7-48.1)	31.5 (26.0-37.5)	5170
F	46.3 (40.7-51.9)	33.5 (27.9-39.6)	5087
P-value*	**0.001**	**0.048**	
Region			
Southern	52.5 (40.7-64.0)	40.4 (29.9-51.9)	3040
Highlands	30.6 (22.8-39.8)	22.7 (14.0-34.6)	1702
Momase	74.0 (64.3-81.8)	47.0 (34.1-60.4)	2364
Islands	29.3 (18.7-42.6)	25.4 (16.5-36.8)	3151
P-value*	**0.001**	**0.007**	
Total	44.3 (38.8-49.9)	32.5 (27.0-38.4)	10,257

* Chi-square test

Table 4-6: Key indicators of mosquito net usage in children under five years of age (weighted analysis)

Background characteristics	Percentage of children under five years of age who slept under a net last night	Percentage of children under five years of age who slept under an LLIN last night	Number of children under five years of age
	% (95% CI)	% (95% CI)	
Age (in years)			
<1	51.0 (42.4-59.6)	41.0 (32.2-50.5)	285
1	53.2 (44.1-62.2)	40.8 (31.2-51.2)	301
2	56.1 (46.7-65.0)	43.2 (33.8-53.1)	312
3	48.1 (38.6-57.7)	35.5 (27.5-44.5)	342
4	50.7 (42.5-58.9)	37.5 (29.2-46.5)	359
P-value*	0.510	0.453	
Sex			
M	53.2 (46.0-60.2)	40.0 (32.6-47.8)	856
F	50.1 (43.2-57.1)	38.9 (31.9-46.3)	743
P-value*	0.305	0.686	
Region			
Southern	55.7 (43.9-66.9)	45.1 (34.1-56.7)	476
Highlands	35.9 (25.1-48.3)	27.1 (16.8-40.5)	215
Momase	80.7 (74.1-85.8)	55.4 (38.1-71.4)	392
Islands	38.4 (26.2-52.4)	32.7 (23.0-44.1)	516
P-value*	**<0.001**	**0.014**	
Total	51.8 (45.4-58.1)	39.5 (32.8-46.5)	1599

* Chi-square test

Table 4-7: Key indicators of mosquito net usage in pregnant women (weighted analysis)

Background characteristics	Percentage of women who slept under a net last night % (95% CI)	Percentage of women who slept under an LLIN last night % (95% CI)	Number of women age 15-49	Percentage of pregnant women who slept under a net last night % (95% CI)	Percentage of pregnant women who slept under an LLIN last night % (95% CI)	Number of pregnant women age 15-49
Region						
Southern	57.6 (46.2-68.3)	44.6 (33.6-56.1)	704	72.0 (45.1-88.9)	56.9 (39.2-72.9)	36
Highlands	32.5 (23.8-42-5)	22.8 (13.8-35.2)	431	44.9 (26.2-65.2)	27.1 (13.0-48.0)	25
Momase	75.3 (64.6-83.5)	49.6 (36.4-63.0)	595	88.1 (61.7-97.2)	63.6 (37.6-83.5)	22
Islands	33.8 (22.1-47.8)	29.1 (19.5-41.0)	752	46.5 (23.9-70.6)	37.8 (20.4-58.9)	49
P-value*	**<0.001**	**0.005**		**0.049**	**0.067**	
Total	47.6 (41.7-53.6)	35.0 (29.2-41.4)	2482	56.1 (44.1-67.5)	41.3 (31.6-51.8)	132

* Chi-square test

4.3.2 Reasons for not using a mosquito net

Out of the total of 3639 mosquito nets found during the surveys in post-distribution villages, 2320 (63.8%) nets had been used the previous night. Non-LLINs were used significantly more often than LLINs (68.4% vs. 62.1%, P=0.001).

Most frequently, nets were not used because they were being spared for later use, either for a new house, a visitor or a particular person who was absent during the survey (32.8%). The second most common reason was that a net was considered "expired" either because it was damaged, had too many holes, was old or too dirty (17.7%). Other frequently cited reasons included: (perceived) absence of mosquitoes (11.9%), feeling too hot under the net (11.0%) or simply a dislike or complacency about the use of mosquito nets (11.0%). Significantly fewer LLINs were considered expired than non-LLINs. On the other hand, significantly more LLINs were not used because people disliked the nets or could not be bothered than non-LLIN nets (Table 4-8).

Table 4-8: Reported reasons for not using a particular mosquito net the previous night

	Unused net (%)		
Reported reasons for not using net §	**Non-LLIN**	**LLIN**	**P-value***
Net spared / reserved for somebody else	33.3	35.9	0.274
Expired (damaged, old, dirty)	22.8	16.1	**0.010**
No mosquitoes	12.1	13.1	0.625
Too hot	13.8	10.8	0.169
Dislike net / can not be bothered / forgot	6.9	13.3	**0.004**
Problem with installation, incl. room size	1.5	0.9	0.416
Considered too valuable	0.4	1	0.314
Other	4.4	5.4	0.477
Total nets unused	31.6	37.9	0.001

* Per net, more than one reason could be given § Chi-square test

As reflected in the previously presented usage data per province, more of the nets were used in Momase than in the other provinces. In all except the Islands region, sparing the net for later or somebody else was the most frequently cited reason for not using a particular net. In Southern region, the (perceived or real) absence of mosquitoes was also frequently mentioned while in the other three regions, many nets were not used because they were damaged, old or dirty. In the Islands, a general dislike of using nets and complacency were commonly mentioned as was the impression that sleeping under a net was too hot (Table 4-9).

Table 4-9: Reported reasons for not using a particular mosquito net the previous night by region

Reason for not using net last night[§]	Region (%)				
	Southern	Highlands	Momase	Islands	P-value*
Net spared / reserved for somebody else	43.7	48.8	84.1	19.1	**<0.001**
Expired (damaged, old, dirty)	11.6	**15.6**	**4.6**	**24.3**	**<0.001**
No mosquitoes	**22.0**	1.0	0.0	11.6	**<0.001**
Too hot	10.1	1.4	0.0	17.6	**<0.001**
Dislike net / can not be bothered / forgot	7.4	5.7	0.0	**18.7**	**<0.001**
Problem with installation, incl. room size	0.5	1.9	0.0	1.2	0.352
Considered too valuable	0.0	3.8	4.6	0.0	**<0.001**
Other	1.0	12.3	6.8	5.4	**<0.001**
Total nets unused	36.5	51.1	6.9	55.5	**<0.001**

* Chi-square test [§] Per net, more than one reason could be given

5 RESULTS: TREATMENT SEEKING FOR FEVER

5.1 Fever rates

For a total of 10,968 individuals in post-distribution villages, information on recent fever episodes was available. Overall, 10.6% (95% CI 8.5-13.3) reported to have had an episode of fever in the 14 days prior to the interview. Fever rates decreased significantly with age, amounting to 19.1% (16.3-22.3) in children under 5 years, 9.6% (7.0-13.0) in 5-14 year olds and 9.0% (8.5-13.3) in the age group 15 years and older (P<0.001). Differences were statistically significant within as well as between the regions (Figure 5-1). The highest fever rates were recorded in Southern and Islands regions, whereas Momase reported relatively few cases.

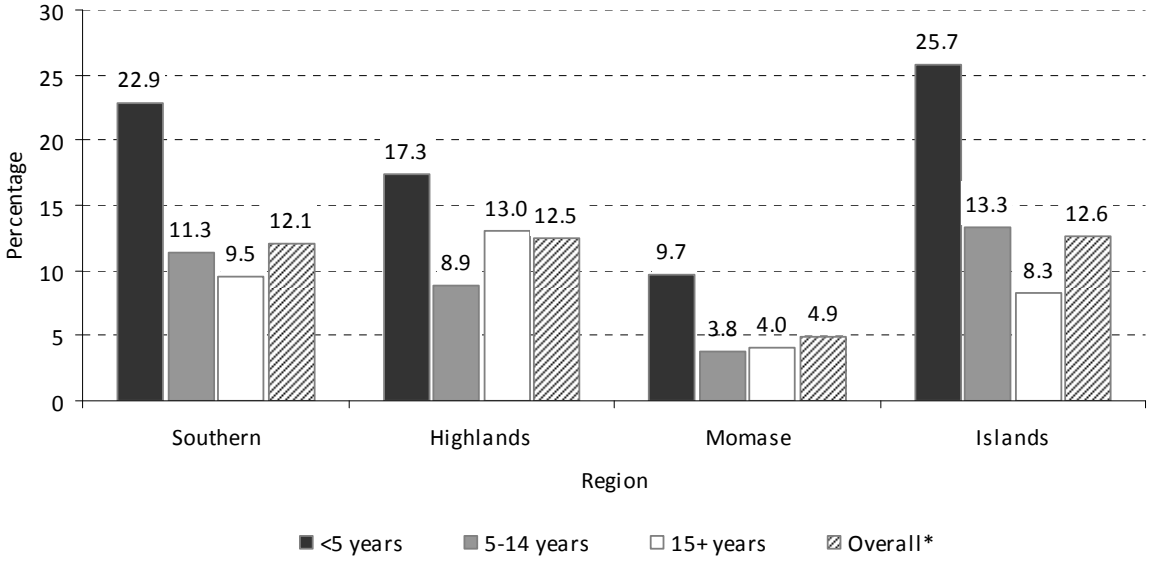


Figure 5-1: Recent episodes of fever by age group and region

Weighted proportions

5.2 Treatment seeking

In total, 45.4% (36.8-54.3) of the recently febrile household members attended a health facility during their illness (17.3% an aid post, 27.9% a health centre, 3.5% a hospital). Health facility attendance did not differ significantly between regions or between age groups.

Drugs were taken by 55.4% (49.1-61.6) of the individuals with recent fever. Drug intake did not differ between age groups, but statistically significant differences were evident between sex and regions. Recent fever cases in the Islands received more frequently a drug than in the other regions. Drugs in general were more often taken by male household members, while antimalarials were more frequently administered to female patients. Antimalarials were taken in 38.8% (31.4-46.8) of the cases, yet only 11.3% (8.9-14.4) received the recommended first-line treatment for uncomplicated malaria composed of a combination of chloroquine plus sulphadoxine-pyrimethamine (SP) or amodiaquine plus SP. Among children under 5 years of age, only 10% (6.5-15.0) received the recommended treatment regimen (Table 5-1).

Table 5-1: Treatment seeking for recent episodes of fever

Background characteristics	Health facility attendance	Drug	Antimalarial	First-line treatment[§]	Number of fever episodes
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	
Age (in years)					
<5	44.5 (38.1-51.2)	55.0 (47.2-62.7)	37.3 (31.4-45.6)	10.0 (6.5-15.0)	342
5-14	52.9 (38.2-67.2)	62.6 (50.3-73.4)	49.8 (36.3-63.4)	15.2 (11.3-20.1)	317
15+	42.1 (31.9-53.0)	51.9 (43.5-60.2)	33.4 (25.0-43.0)	10.1 (7.2-14.0)	543
P-value*	0.198	0.198	**0.031**	0.068	
Sex					
M	49.3 (38.9-59.7)	50.1 (44.1-56.1)	42.9 (33.6-52.7)	12.3 (9.2-16.2)	620
F	41.6 (33.9-49.6)	60.6 (52.6-68.1)	34.7 (28.4-41.6)	10.4 (7.3-14.5)	583
P-value*	**0.016**	**0.003**	**0.011**	0.376	
Region					
Southern	40.0 (29.5-51.6)	48.1 (39.4-56.8)	36.8 (27.9-46.8)	14.3 (8.6-22.9)	401
Highlands	43.8 (22.5-67.7)	45.8 (26.5-66.4)	32.2 (13.5-59.3)	7.6 (4.3-13.3)	215
Momase	38.7 (19.7-62.0)	44.8 (23.2-68.6)	36.7 (19.9-57.6)	11.7 (4.1-28.9)	149
Islands	52.6 (44.1-60.9)	72.3 (64.7-78.9)	47.0 (37.5-56.7)	12.8 (9.0-18.1)	439
P-value*	**0.026**	**0.026**	0.454	0.356	
Total	45.4 (36.8-54.3)	55.4 (49.1-61.6)	38.8 (31.4-46.8)	11.3 (8.9-14.4)	1204

* Chi-square test [§] Chloroquine + SP or amodiaquine + SP

The majority of cases attending a health facility received an antimalarial treatment (74.2%, 66.2-80.8) and 22.4% (17.2-28.6) receive the recommended first-line treatment. Of those patients that did not attend a health facility, only 9.3% (5.7-15.1) received an antimalarial and 2.1% (0.8-5.3) the recommended first-line regimen. These differences were both statistically significant (P<0.001).

Of those cases who did not receive the recommended antimalarial combination regimen despite attending a health facility, 29.8% received chloroquine, 23.5% amodiaquine, 12.6% paracetamol, 5.6% quinine, 5% SP and 3.5% artemether or artesunate, either as monotherapy, or in a combination not recommended in the treatment guidelines. 3.4% (1.7-6.6) of these cases were treated with artemether/artesunate plus SP which is recommended for severe or treatment-failure malaria.

6 RESULTS: PARASITAEMIA PREVALENCE

6.1 Sample characteristics

A total of 6814 blood slides collected from household members in 53 villages were read by light microscopy. This included villages covered with outcome surveys as well as pre-intervention villages in Sentinel Sites. In the Highlands, only villages below 1600 meters altitude were included in the analysis. Also excluded were villages in which less than 40 slides were collected. The number and age distribution of the participants is presented in Table 6-1[4]. Not all age groups were represented equally in the overall sample and consequently comparisons of parasitaemia over all age groups between regions should be interpreted with caution.

Table 6-1: Number of blood slides by age group and province

Age group (years)	Southern		Highlands <1600m		Momase		Islands		P-value
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
0.5-4	299	14.9	75	10.8	277	14.6	387	18.0	
5-14	569	28.4	185	26.5	525	27.7	652	30.3	
15+	1134	56.6	437	62.7	1095	57.7	1111	51.7	<0.001*
Mean age	23.2 (22.4-24.0)		25.7 (24.4-27.1)		23 (22.2-23.9)		21.2 (20.5-21.9)		<0.001§
	2002		697		1897		2150		

*Chi-square test §Analysis of variance (3 df)

6.2 Prevalence of parasitaemia

A total of 1239 (18.2%) blood slides were positive for *Plasmodium* parasites. Across all age groups, the highest prevalence of parasitaemia was found in the Islands region, the lowest in the Highlands. Across all age groups, the dominant species was *P. falciparum*, except for the Islands region, where slightly more people were found with a *P. vivax* infection (Table 6-2). The highest levels of parasitaemia found were 63.3% prevalence of infection with any species in West New Britain, 44.7% *P. falciparum* infection in Milne Bay (Samarai-Murua) and 29.3% *P. vivax* infection in Sandaun (Yapsie).

[4] Differences between the total numbers in Table 6-1 and the overall total of slides are due to missing age information of study participants

Table 6-2: Parasitaemia prevalence across all age groups by region

Region	Slides read	Parasitaemia prevalence (%)				
		All species	*P. falciparum**	*P. vivax**	*P. malaria/ovale*	Mixed[§]
Southern	2018	11.6	7.8	2.9	0.1	0.4
Highlands <1600m	708	11.4	7.2	2.5	0.1	0.8
Momase	1922	19.8	10.5	6.7	0.2	1.9
Islands	2166	25.1	8.2	11.2	0.6	3.4
Total	6814	18.2	8.6	6.6	0.3	1.8

*Monoinfections [§]Any species

Considering the significant difference in age distribution between the regional samples and the correlation of age with parasitaemia, results were stratified into three age groups (under five years, five to 14 years, and 15 years and above). In Southern and Highlands region, the highest prevalence of infection with any species was found in children under five years, while in Momase and Island regions, the highest burden of infection was concentrated in the age group 5-14 years. *P. falciparum* infections decreased with age in Southern and Highlands while in Momase and Islands it was highest in the 5-14 year olds. *P. vivax* infections showed a decreasing trend with age, except for the Highlands region where more vivax-infections were found in 5-14 years olds than in the other age groups. Overall, *P. vivax* and mixed infections were most prevalent in the Islands (Figure 6-1).

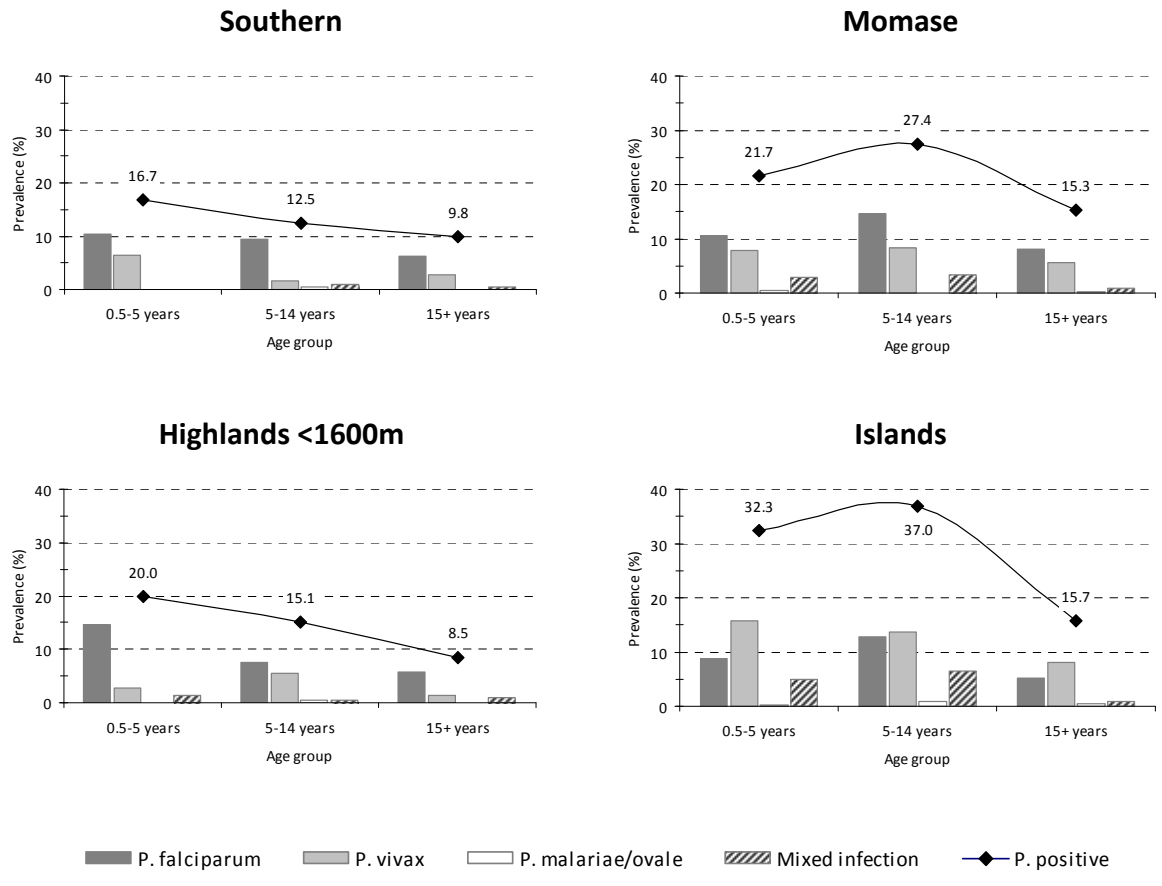


Figure 6-1: Parasitaemia prevalence by age group and region

Infections with *P. malaria* and *P. ovale* were rare and mixed infections were most common in areas with higher parasitaemia. While Figure 6-1 presents general regional trends, there were significant variations within the regions (Figure 6-3).

Generally, higher parasitaemia levels were measured at lower altitudes (Figure 6-2). However, even in the lowlands, some areas had very low levels of infection (<10%), particularly in the Southern region.

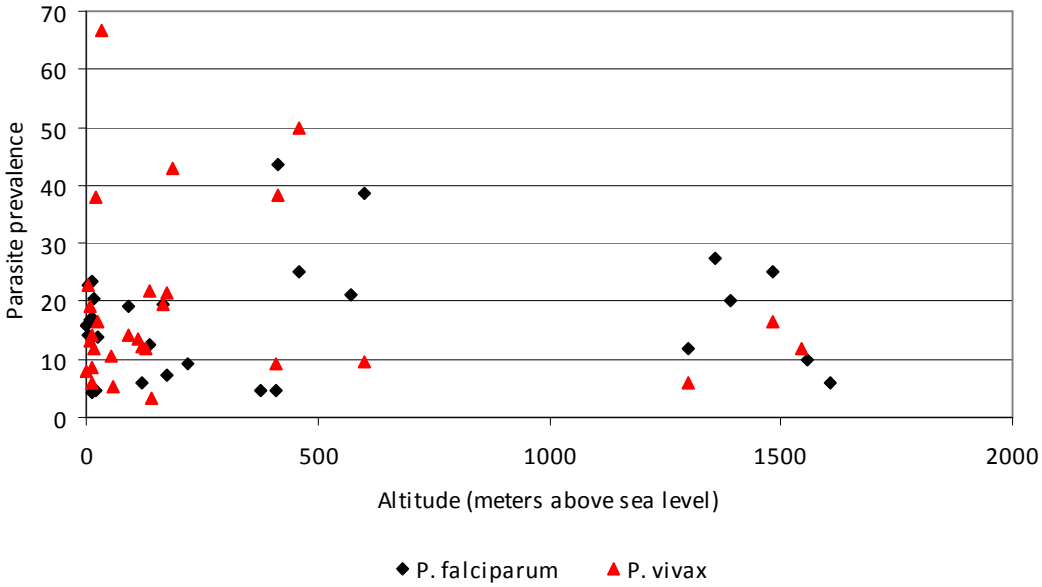


Figure 6-2: Parasitaemia in children <5 years of age by altitude

Locations with 0% prevalence not shown

6.2.1 Parasitaemia and mosquito net use

Out of the 6814 collected slides, 801 (11.8%) were collected in villages with a mosquito net usage rate of 80% or above. Adjusted for age, altitude and region, individuals living in villages with 80% or more net usage were significantly less likely to be infected with *Plasmodium* (Odds Ratio [OR] 0.68, 95%CI 0.53-0.86, P=0.001). This result was almost equally significant for *P. falciparum* (OR 0.69, 0.52-0.92, P=0.012) and *P. vivax* (OR=0.67, 0.46-0.98, P=0.040).

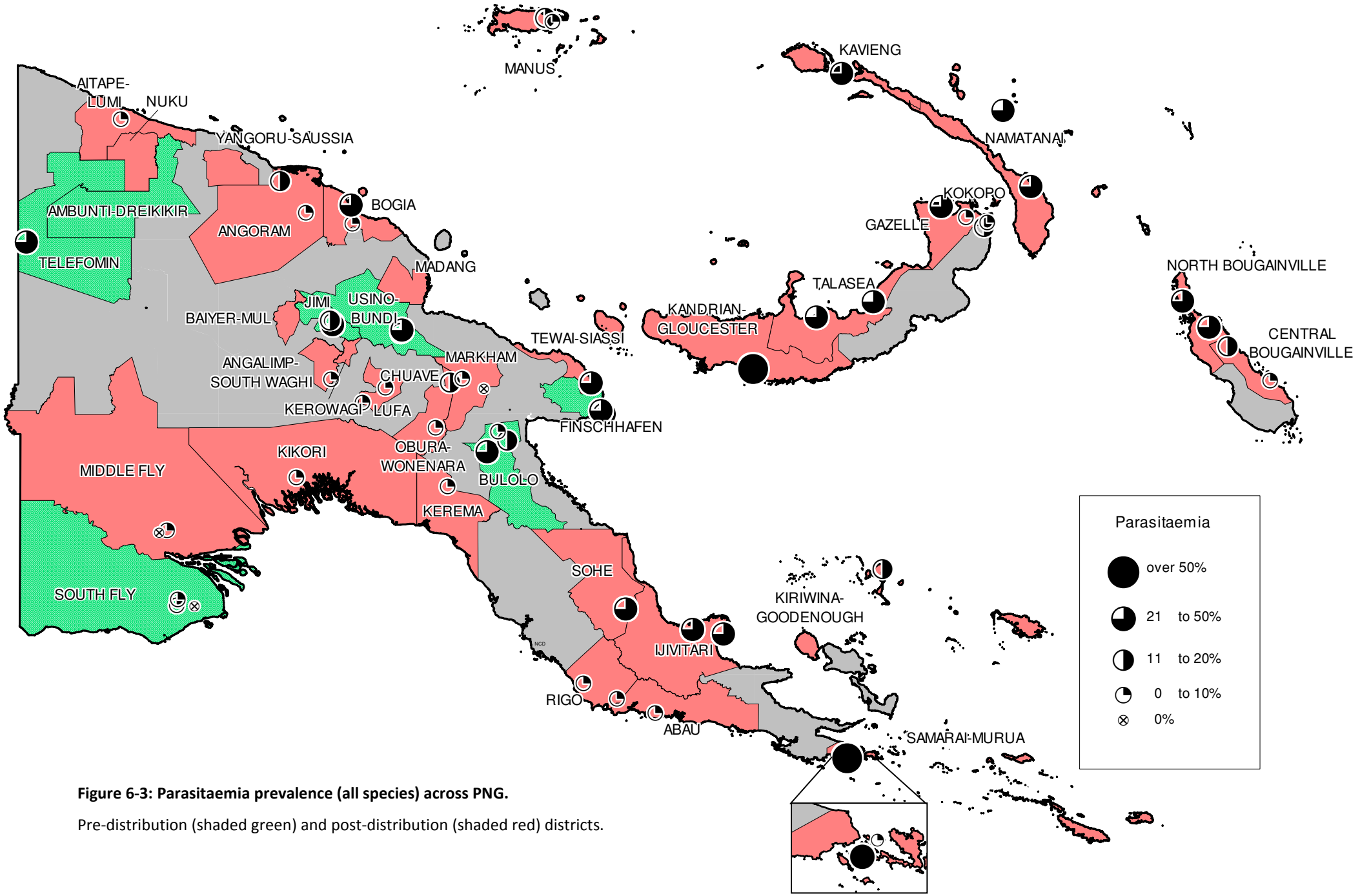


Figure 6-3: Parasitaemia prevalence (all species) across PNG.

Pre-distribution (shaded green) and post-distribution (shaded red) districts.

7 RESULTS: MALARIA INCIDENCE IN SENTINEL SITES

7.1 Sample characteristics

For longitudinal monitoring of disease trends and intervention coverage, seven Sentinel Sites were selected as described in the Methods section of this report. The characteristics and activities carried out in each site are summarized in Table 7-1.

Table 7-1: Sentinel Site activities

Region	Province	District	Health facility surveillance	Surveillance period	Household surveys	Survey dates
Southern	Western	South Fly	Wipim Health Centre	16/04 - 19/06/2009	PODARE TABAKIP KURU	17/04 - 25/04/2009
Highlands	Western Highlands	Jimi	(Tabibuga Health Centre)	No surveillance	BRAIMBA BUNBI TSINGOROPA	07/05 - 14/05/2009
Momase	Morobe	Finschhafen	Braun Memorial Hospital	08/06 - 21/08/2009	GODOWA GINGALA SIUKO	06/06 - 12/06/2009
		Bulolo	Mumeng Health Centre	28/01 - 31/03/2009	BUNDUN GWASAK MANGGA	12/02 - 20/02/2009
	Madang	Usino-Bundi	Sausi Sub-Health Centre	20/10 - 18/12/2008	MAUNO KESOWAI KOKOFINE	14/12 - 21/12/2008
	East Sepik	Ambunti-Drekikir	Dreikikir Health Centre	30/10 - 19/12/2008	TUMAM YAUOTONG BENENG	30/10 - 07/11/2008
	West Sepik	Telefomin	(Yapsie Health Centre)	No surveillance	BITAPENA YAPSIE SKONGA IMNAI	10/08/- 17/08/2009

In each site, household surveys were conducted in three villages (four villages in Telefomin district), entomology surveys in two villages, and health facility outpatient surveillance for a period of approximately two months in the local health centre. Due to the timing of the LLIN distribution, no outpatient surveillance was conducted in Jimi and Telefomin. Household survey results were presented as non-randomized comparisons in previous chapters.

7.2 Malaria incidence and attributable fraction

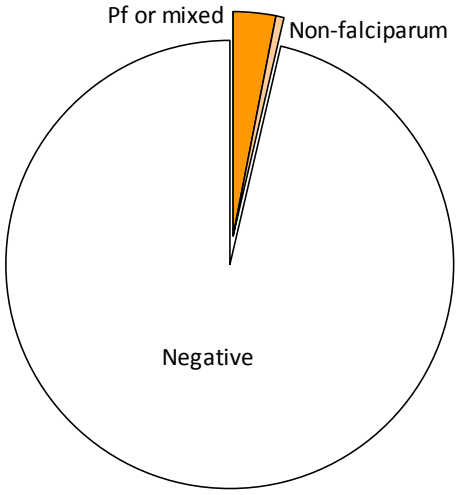
The incidence of RDT confirmed malaria differed significantly between the Sentinel Sites, as did the fraction of fever cases attributable to malaria. The highest malaria incidence as well as malaria attributable fraction was measured in Dreikikir in East Sepik province, the lowest in Wipim Health Centre in Western province. The detailed results for each site are presented below. Data on catchment populations were derived from the health facility records. The diagnostic categories were based on the ICT test that was used.

7.2.1 Wipim Health Centre, South Fly district, Western province

Wipim Health Centre, situated in South Fly district at 52 meters altitude, serves 9000 people in 22 villages. Active malaria surveillance covered a period of 55 days, between 16/04 and 19/06/2009. During this period, the health centre was closed for several days. The surveillance period was characterised by heavy rainfall and floods in the surrounding area. Attendance at the health facility was comparably low resulting in a total of only 137 patients with a recent history of fever being screened. An RDT was performed on each of these patients. The RDT-confirmed incidence of malaria was estimated at 5 cases per month for the period under surveillance. 67.9% of the patients reported to have slept under a mosquito net the night before attending the health facility. Key results from Wipim are presented in Table 7-2.

Table 7-2: Malaria incidence at Wipim Health Centre

Indicator	Number	Percent
Total patients screened	137	
Age (in years)		
<5 years	20	14.6
5-14 years	42	30.7
15+ years	75	54.7
Sex		
M	65	47. 5
F	72	52.6
Axillary temperature		
Over 37.5°C	57	41.6
RDT	137	
P. falciparum	0	-
P. falciparum or mixed	4	2.9
Non-falciparum	1	0.7
Negative	132	96.4
Total RDT positive	**5**	**3.7**
Number of surveillance days	55	
Average RDT positive per day	0.1	
Extrapolated monthly incidence	**3**	

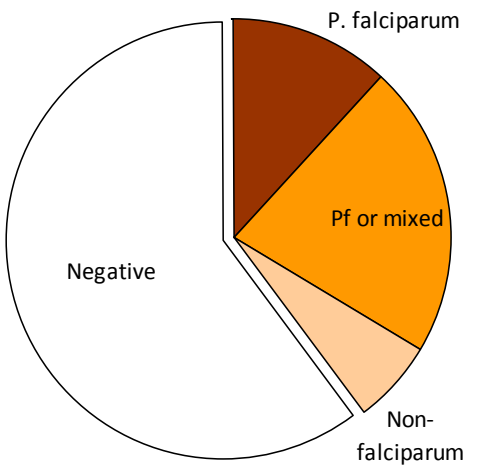


7.2.2 Braun Memorial Hospital, Finschhafen, Morobe province

The Braun Memorial Hospital is located in Gagidu, Finschhafen district, at 6 meters altitude and serves 14000 people in 30 villages. Active case surveillance was carried out in the outpatient clinic of the hospital over a period of 75 days, between 8/06 and 21/08/2009. A total of 266 patients were screened during that period and an RDT was performed on each patient. The RDT-confirmed incidence of malaria was estimated at 42 cases per month for the period under surveillance. 78.6% of the patients reported to have slept under a mosquito net the night before attending the hospital. Key results from Braun Memorial Hospital are presented in Table 7-3.

Table 7-3: Malaria incidence at Braun Memorial Hospital in Finschhafen

Indicator	Number	Percent
Total patients screened	266	
Age (in years)		
<5 years	102	38.4
5-14 years	82	30.8
15+ years	82	30.8
Sex		
M	124	46.6
F	140	52.6
Axillary temperature		
Over 37.5°C	96	36.1
RDT	259	
P. falciparum	31	12.0
P. falciparum or mixed	57	22.0
Non-falciparum	16	6.2
Negative	158	61.0
Total RDT positive	**104**	**40.2**
Number of surveillance days	75	
Average RDT positive per day	1.4	
Extrapolated monthly incidence	**42**	

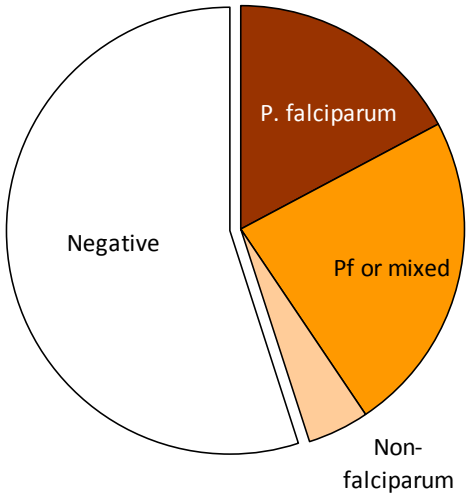


7.2.3 Mumeng Health Centre, Bulolo district, Morobe province

Mumeng Health Centre, situated in Bulolo district at 940 meters altitude, serves 17000 people in 10 villages. It had active surveillance over a period of 54 days, between 28/01 and 31/03/2009. A total of 473 patients were screened and 471 RDTs performed during that period. The RDT-confirmed incidence of malaria was estimated at 117 cases per month for the period under surveillance. 34.5% of the patients reported to have slept under a mosquito net the night before attending the health facility. Key results from Mumeng are presented in Table 7-4.

Table 7-4: Malaria incidence at Mumeng Health Centre

Indicator	Number	Percent
Total patients screened	473	
Age (in years)		
<5 years	197	41.7
5-14 years	109	23.0
15+ years	167	35.3
Sex		
M	243	51.4
F	230	48.6
Axillary temperature		
Over 37.5°C	178	37.6
RDT	471	
P. falciparum	80	17.0
P. falciparum or mixed	110	23.4
Non-falciparum	20	4.3
Negative	258	54. 8
Total RDT positive	**210**	**44.6**
Number of surveillance days	54	
Average RDT positive per day	3.9	
Extrapolated monthly incidence	**117**	

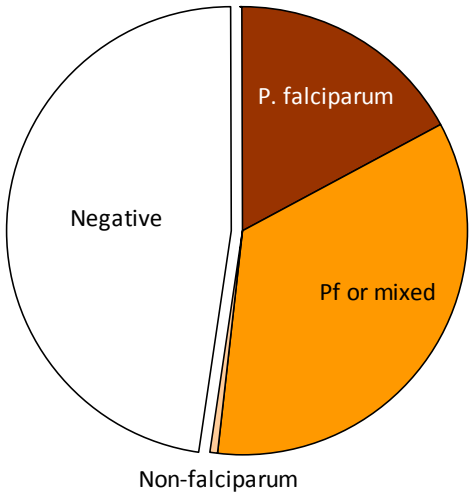


7.2.4 Sausi Sub-Health Centre, Usino-Bundi district, Madang province

Sausi Sub-Health Centre which is operated by the Evangelical Brotherhood Church of PNG (EBC), is situated in the Ramu valley in Usino-Bundi district, at 160 meters altitude. It serves 6700 people in 21 villages. Active surveillance was carried out over a period of 44 days, between 20/10 and 18/12/2008. A total of 461 patients were screened and 460 RDTs performed during that period. The RDT-confirmed incidence of malaria was estimated at 162 cases per month for the period under surveillance. 93.3% of the patients reported to have slept under a mosquito net the night before attending the health facility. Key results from Mumeng are presented in Table 7-5.

Table 7-5: Malaria incidence at Sausi Sub-Health Centre

Indicator	Number	Percent
Total patients screened	461	
Age (in years)		
<5 years	184	39.9
5-14 years	126	27.3
15+ years	148	32.1
Sex		
M	248	53.8
F	203	44.0
Axillary temperature		
Over 37.5°C	178	37.6
RDT	460	
P. falciparum	78	17.0
P. falciparum or mixed	157	34.1
Non-falciparum	3	0.7
Negative	218	47.4
Total RDT positive	**238**	**51.7**
Number of surveillance days	44	
Average RDT positive per day	5.4	
Extrapolated monthly incidence	**162**	

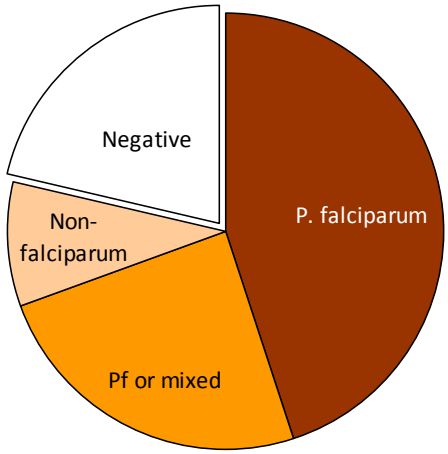


7.2.5 Dreikikir Health Centre, Ambunti-Dreikikir district, East Sepik province

Dreikikir Health Centre, situated in Ambunti-Dreikikir district at 420 meters altitude, serves 8300 people in 41 villages. It had active surveillance over a period of 47 days, between 30/10 and 19/12/2008. A total of 390 patients were screened and 387 RDTs performed during that period. The RDT-confirmed incidence of malaria was estimated at 190 cases per month for the period under surveillance. 56.4% of the patients reported to have slept under a mosquito net the night before attending the health facility. Key results from Mumeng are presented in Table 7-6.

Table 7-6: Malaria incidence at Dreikikir Health Centre

Indicator	Number	Percent
Total patients screened	390	
Age (in years)		
<5 years	227	58.2
5-14 years	113	29.0
15+ years	47	12.1
Sex		
M	187	48.0
F	203	52.1
Axillary temperature		
Over 37.5°C	272	69.7
RDT	387	
P. falciparum	170	43.9
P. falciparum or mixed	92	23.8
Non-falciparum	35	9.0
Negative	81	20.9
Total RDT positive	**297**	**76.7**
Number of surveillance days	47	
Average RDT positive per day	6.3	
Extrapolated monthly incidence	**190**	



8 RESULTS: AVAILABILITY OF MALARIA DIAGNOSIS AND TREATMENT IN HEALTH FACILITIES

8.1 Sample characteristics

A total of 66 health facilities were visited during the cross-sectional surveys in post-campaign villages and Sentinel Sites in 17 provinces. 18 (20.5%) of the facilities were aid posts (AP), 41 (46.6%) health centres or sub-health centres (HC/SC), two (2.3%) an urban clinic or day-clinic, and 5 (5.7%) were hospitals. An aggregated analysis was done for health facilities from all sites since service delivery in health facilities is not linked to the LLIN distribution campaign. The urban clinic and day-clinic were excluded from the analysis.

8.2 Availability of diagnostic facilities for malaria

A total of 31.7% of the HC/SC had a working microscope and in 27.5% there was staff trained to use it while 60.0% of the hospitals had a working microscope as well as trained staff. APs had neither microscope nor trained staff.

RDTs for malaria were available in 41.5% of all HC/SC and in 53.7% there was at least one staff member trained to use RDTs. Only one (20.0%) of the hospitals had RDTs in stock and in three (60.0%) there was at least one staff member trained to use the tests. In none of the APs were RDTs available but in three (16.7%) of the APs a staff member had been trained in using RDTs (Table 8-1).

Table 8-1: Diagnostic tools for malaria

Diagnostic tools	Facility type* (%)				
	AP	HC/SC	Hospital	Total	P-value[§]
Working microscopy[‡]	0	31.7	60.0	25.0	**0.001**
RDT	0	41.5	20.0	28.1	**0.004**
Any diagnostic facility for malaria	0	53.7	60.0	39.1	**<0.001**

* AP = Aid post; HC/SC = Health centre/sub-health centre

[‡] Microscope works and reagents are available [§] Fisher's exact test

8.3 Availability of antimalarial drugs

There were significant differences between the proportions of different health care providers stocking antimalarial medicines. Only 66.7% of the APs, but 95.1% of the HC/SCs and all hospitals reported to have antimalarials in stock. The recommended first-line

regimens were available in only 44.4% of the AP, yet in 90.2% of the HC/SCs and in 80% of the hospitals (P=0.014). Artesunate or artemether (monotherapies) were significantly more frequently found in HC/SCs and hospitals than in APs. No statistically significant difference was found for other individual drugs. Overall, chloroquine and amodiaquine were the most frequently stocked antimalarial drugs (Table 8-2).

Table 8-2: Availability of antimalarials in health facilities

Antimalarial	Facility type* (%)				
	AP	HC/SC	Hospital	Total	P-value[§]
Chloroquine	83.3	100	100	94.8	0.088
Amodiaquine	75.0	97.4	100	93.1	0.064
Sulphadoxine-pyrimethamine (SP)	75.0	94.9	80.0	87.9	0.065
Quinine injections	58.3	84.6	100	81.0	0.117
Primaquine	91.7	84.6	80.0	86.2	0.848
Artesunate/artemether	22.2	70.7	80	57.6	**0.001**
Recommended first-line treatment[‡]	44.4	90.2	80	75.8	**0.001**
Any antimalarial	66.7	95.1	100	87.9	**0.014**

* AP = Aid post; HC/SC = Health centre/sub-health centre

[‡] Chloroquine and SP or amodiaquine and SP [§] Fisher's exact test

9 DISCUSSION AND RECOMMENDATIONS

9.1 LLIN distribution campaign

With the distribution of over 2 million nets, the GFATM supported malaria control programme achieved increased coverage of mosquito nets, particularly LLINs, across PNG. Significantly higher levels of ownership could be noted in villages covered with the campaign if compared to villages in which the campaign had not yet been carried out. Nevertheless, the set targets of 80% ownership and 80% usage in children under five years and pregnant women after the end of the distribution campaign were not reached. In particular, a major discrepancy was noted between household ownership of nets and actual usage.

Anecdotal evidence from distribution campaigns suggested that the distribution ratio of 2.5 people per net was a major obstacle to achieving high coverage and usage. In addition, provincial and district heath officers complained that the number of nets supplied were not sufficient to supply all households counted in the pre-distribution census. The population figures calculated based on the 2000 national census and the numbers of houses and individuals counted by district and village officials did not match in many occasions. It is unclear whether this discrepancy is attributable to inaccurate national census or growth rate figures, to neglected population movements, or to overestimations during the population surveys carried out specifically for the net distribution. Most likely, all factors contributed to the difference. Additional operational difficulties in reaching villages and households were often reported. These included difficult accessibility of remote villages due to lack of roads, closed airstrips, bad weather, or tribal conflicts. Households lacking a mosquito net therefore often reported that they had been left out during the distribution campaign. While in some occasions, nets may not have been reported to the survey team, the failure to cover certain areas was evident in villages in which few people owned a mosquito net.

It is well known from other large-scale campaigns, i.e. childhood vaccinations, that they pose an enormous burden on health systems. Integration of health interventions is therefore paramount to avoid overloading the system. The failure of certain provincial health authorities to integrate the implementation of different interventions became apparent in one particular setting in which the mosquito net campaign was delayed due to an ongoing immunization campaign. Instead of vaccinating children and distributing nets at the same time, three independent village visits had been scheduled for immunization, household census, and distribution of nets. In other occasions, nets supplied to the provinces and intended for free distribution leaked onto the retail market or were sold on the black market. Again in other areas, net distributions were coupled with political campaigns and their timing was therefore dependent on political rather than operational considerations.

Failure to reach the set ownership and usage targets can not only be attributed to problems with the implementation of the campaign. Many households across PNG did own a mosquito

net, but they never used it. The PNG IMR survey team encountered many mosquito nets still in their original packaging. Clearly, many household members either considered the net very valuable, and wanted to spare it for later use, or they simply did not acknowledge the benefits of using a mosquito net.

In order to achieve high ownership and usage of mosquito nets, several issues need to be addressed. Firstly, the campaign implementation needs to be improved. This includes a more accurate determination of the required amount of nets on a district level and the direct use of this information for calculating the amount of nets to be supplied. It also requires better planning by campaign implementers who should try to integrate health interventions at provincial and district levels in order to avoid wasting limited financial and human resources. In addition, implementers need to understand the urgency and benefits of supplying mosquito nets; and political leaders should use their power to support the net distribution rather than use the nets to support their own political goals. Secondly, the prospective net users need to be made aware of the safety and benefits of using mosquito nets every single night. The perceived absence of mosquitoes should not encourage people to sleep without a net.

So far, the strategy of the National Malaria Control Programme has focused on only one channel of net distribution, i.e. large-scale distribution campaigns. The results from this study revealed several issues which indicate that a reliance on only one net distribution strategy may not be sufficient. For instance, many people refrain from using their mosquito net and spare it for later use. In a situation in which there is no constant supply of mosquito nets, the nets become more valuable and people may be more reluctant to use their net fearing that once it is expired it will not be possible to obtain a new one. In addition, even the best campaign is unlikely to achieve 100% coverage. Particularly in PNG, where accessibility of villages is often unpredictable and dependent upon weather conditions and the local law and order situation. Individuals who just move to a village or children who are newly born may also easily miss the opportunity to obtain a net. Before the next distribution round reaches their village, these people will not be protected from malaria unless they find another way of obtaining nets.

Large-scale campaigns are probably the best method for achieving high net coverage within a comparably short time frame (“catch-up” strategy). However, sustainable long-term solutions should also include other distribution mechanisms (6;7). Operational research can help to identify complementary strategies suitable to the PNG setting.

9.2 Fever episodes and treatment seeking

This report provides basic evidence of fever rates and treatment seeking strategies for fever episodes in PNG. The definition of fever episodes relied exclusively on self-reporting by household heads and a recall-bias leading to over-reporting of fever is possible. The 2006 Demographic and Health Survey (DHS) estimated 7% recent fever episodes in children under

three years of age which is considerably lower than the 19.6% (16.6-22.9) in the same age group found in this evaluation (data for this age group not reported in main text) (8).

Treatment seeking for fever episodes needs to be assessed in the context of the local malaria epidemiology. Asymptomatic parasitaemia is common in semi-immune populations in PNG and, particularly in children, clinical disease is more likely to develop due to an infection with *P. falciparum* than with *P. vivax* (9). Yet high prevalences of both species and health facility based data on malaria attributable fractions suggest that in some areas, particularly Momase and Islands regions, between 40% and 80% of fever cases may be due to malaria.

Malaria control strategies advertise prompt care seeking at health facilities and treatment with the recommended first-line antimalarial(s). In PNG, less than half of the fever cases were brought to a health facility. Considering that in PNG, options for laboratory based diagnosis and antimalarial medicines are largely limited to health facilities, the majority of fever cases lacked the opportunity of obtaining evidence-based treatment with appropriate drugs. In general, treatment seeking for fever in PNG is poorly understood and little is known about the burden of clinical malaria illness at the level of the household. Decision-making in the moment of a disease episode should therefore be further investigated, taking into account locally available resources and treatment options.

This evaluation only investigated the types of antimalarial used without considering dosage or timing. If dosage was also taken into account, the proportion of cases treated appropriately would most probably have been considerably lower (10). The household surveys did also not investigate whether fever cases had been diagnosed by microscopy or RDT or treatment was presumptive based on clinical signs and symptoms. In light of the differences between, for example, Wipim (3.7% of the fever attendances positive for plasmodia) and Dreikikir (76.7%) the importance of introducing laboratory-based tools for the diagnosis of malaria cannot be overemphasised. The Round 3 introduction of RDTs to facilities without microscopy resulted in 41.5% health centres or sub-health centres having RDTs in stock; however, RDTs were not found in any of the aid posts which are often the nearest point of care.

In addition to the lack of diagnostic tools, the majority of aid posts did not have the recommended combination of first-line antimalarial drugs in stock. Artesunate or artemether and quinine for the treatment of severe or treatment-failure malaria were only available in 22.2% and 58.3% of the aid posts, respectively. Considering that 17% of recent fever cases reported seeking care from aid posts, their level of health care provision needs to be addressed urgently.

The Round 8 grant proposal includes the introduction of home-based management of malaria (HMM) in order to increase treatment rates. HMM has been promoted in African settings where inadequate self-treatment with drugs bought from retailers is common (11). However, a controversy exists about whether ACTs should be widely used in HMM without provision of proper diagnosis (12;13). The PNG situation is slightly different since self-medication with shop-bought drugs is not common in rural areas. Only 18.8% of fever patients treated their illness with a drug (data not shown in main text) and 9.3% with an

antimalarial without attending a health facility. Options for obtaining medications are limited in rural area and the promotion of home-based management would require the introduction of village health workers. An alternative and probably more sensible option could be the renovation and strengthening of the existing aid post network.

9.3 Epidemiology of malaria infection

The household surveys conducted for this evaluation provide for the first time country-wide data on malaria prevalence. Since the cessation of the malaria eradication programme in PNG in the 1980s, detailed prevalence data were only generated during the Highlands malaria surveys carried out by PNG IMR (14-18) and in selected areas with intensive malaria research, such as the Wosera in East Sepik (19;20) and the Madang North Coast (21).

P. falciparum was the dominant species in many areas, including malaria endemic parts of the highlands provinces (<1600 meters altitude) and an increasing importance of *P. vivax* with altitude could not be identified. However, this may be related to the fact that in the Highlands blood slides were only collected in areas where malaria was known to be endemic. The importance of *P. vivax* was more striking in the Islands, where *P. falciparum* infection was less common than *P. vivax* infection in all age groups. This finding will be important for the roll-out of *P. vivax* specific treatment. While the importance and potential severity of vivax malaria is now more widely acknowledged (22), the safety of vivax-treatment needs to be guaranteed, particularly when used on a large scale. Currently, the treatment of vivax malaria is limited to the use of Primaquine against hypnozoites alongside an ACT. However, considering the danger of haemoglobinuria following the use of primaquine in patients with severe G6PD deficiency, the prevalence of G6PD deficiency should be investigated in areas with high *P. vivax* prevalence.

Monitoring the development of parasitaemia will be a central task for the evaluation of the current and future malaria control interventions. While particularly in semi-immune populations parasitaemia prevalence is not equal with clinical disease, a decrease in prevalence will also lead to a decrease in clinical episodes (23). There are already indications of reduced prevalence of parasites in areas with high mosquito net coverage. However, this trend needs to be confirmed over a longer period in time. Particular attention should also be paid to changes in parasite species composition considering that the new first line treatment artemether-lumefantrine showed a lower efficacy against vivax than against falciparum infections (24).

9.4 Monitoring the impact of malaria control interventions

The effect of using ITNs has been well documented, around the world and within PNG (4;25). Previous anecdotal evidence from areas in the Sepik indicated that increased use of ITNs has

already led to a decrease in Malaria in certain communities (Mueller, personal communication). The same effect was suggested by results from this evaluation which showed that malaria prevalence was significantly lower in villages with a high net usage. Nevertheless, to achieve lasting impact, high rates of mosquito net ownership and usage need to be sustained over a long period of time.

In order to closely monitor trends in malaria morbidity, Sentinel Sites were established in seven locations. While the main purpose of these sites is to monitor changes following the implementation of malaria control interventions, they already now provide important evidence on the malaria situation in different settings in PNG. Baseline data showed significant regional differences in malaria attributable morbidity at the level of the health facilities. As little as 3.7% of the outpatient fever cases could be attributed to a malaria infection in Wipim, Western province and data from nearby communities confirmed a low prevalence of malaria infection. On the other hand, data from the Sepik, the Ramu Valley, Bulolo and Finschhafen paint a very different picture with high prevalence and high malaria attributable fraction among health facility fever cases (40-77%). These regional and sub-regional differences underline the need for flexibility in the malaria control programme. Resource allocation should not be limited to high burden settings but more intensive control measures may be required in certain areas to achieve measurable success.

Recently, the combination of efficacious treatment in the form of ACTs with ITNs or indoor residual spraying of insecticide has led to significant decreases in malaria in certain African settings (26;27). This combination of interventions will also form the basis for the Round 8 malaria control programme in PNG. Sentinel Sites will be used to evaluate the effect of LLINs in combination with the new ACT, improved diagnosis, and behaviour change campaigns across PNG on the levels of health facilities, households and mosquito vector populations. An important aspect will also be the continuous monitoring of drug resistance in parasites and insecticide resistance in *Anopheles* vectors. These data from Sentinel Sites should inform the NDoH and provide timely evidence to adjust the national malaria control strategies, if required.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10 REFERENCES

(1) Mueller I, Bockarie M, Alpers M, Smith T. The epidemiology of malaria in Papua New Guinea. Trends Parasitol 2003 Jun;19(6):253-9.

(2) WHO. World Malaria Report 2009. Geneva: World Health Organization; 2009.

(3) Charlwood JD, Graves P. The effect of permethrin-impregnated bednets on a population of Anopheles farauti in coastal Papua New Guinea. Med Vet Entomol 1987 Jul;1(3):319-27.

(4) Lengeler C. Insecticide-treated bednets and curtains for preventing malaria (Cochrane Review). 2004. Cochrane Database of Systematic Reviews.
Ref Type: Generic

(5) WHO. Malaria rapid diagnostic test performance: results of WHO product testing of malaria RDTs: round 1 (2008). World Health Organization; 2009.

(6) Lengeler C, Grabowsky M, McGuire D, deSavigny D. Quick Wins Versus Sustainability: Options for the Upscaling of Insecticide-Treated Nets. Am J Trop Med Hyg 2007 Dec 1;77(6 Suppl):222-6.

(7) Magesa SM, Lengeler C, deSavigny D, Miller JE, Njau RJ, Kramer K, et al. Creating an "enabling environment" for taking insecticide treated nets to national scale: the Tanzanian experience. Malar J 2005 Jul 22;4:34.

(8) NSO. Papua New Guinea Demographic and Health Survey 2006. National Report. Port Moresby: National Statistical Office; 2009.

(9) Michon P, Cole-Tobian JL, Dabod E, Schoepflin S, Igu J, Susapu M, et al. The risk of malarial infections and disease in Papua New Guinean children. Am J Trop Med Hyg 2007 Jun;76(6):997-1008.

(10) Hetzel MW, Obrist B, Lengeler C, Msechu J, Nathan R, Dillip A, et al. Obstacles to prompt and effective malaria treatment lead to low community-coverage in two rural districts of Tanzania. BMC Public Health 2008;8(1):317.

(11) Pagnoni F. Malaria treatment: no place like home. Trends Parasitol 2009 Mar;25(3):115-9.

(12) Pagnoni F, Kengeya-Kayondo J, Ridley R. Letter to the Editor: Artemisinin-based combination treatment in home-based management of malaria. Trop Med Int Health 2005;10(6):621-2.

(13) D'Alessandro U, Talisuna A, Boelaert M. Editorial: Should artemisinin-based combination treatment be used in the home-based management of malaria? Trop Med Int Health 2005;10(1):1-2.

(14) Mueller I, Bjorge S, Poigeno G, Kundi J, Tandrapah T, Riley ID, et al. The epidemiology of malaria in the Papua New Guinea highlands: 2. Eastern Highlands Province. P N G Med J 2003 Sep;46(3-4):166-79.

(15) Mueller I, Taime J, Ivivi R, Yala S, Bjorge S, Riley ID, et al. The epidemiology of malaria in the Papua New Guinea highlands: 1. Western Highlands Province. P N G Med J 2003 Mar;46(1-2):16-31.

(16) Mueller I, Kundi J, Bjorge S, Namuigi P, Saleu G, Riley ID, et al. The epidemiology of malaria in the Papua New Guinea highlands: 3. Simbu Province. P N G Med J 2004 Sep;47(3-4):159-73.

(17) Mueller I, Namuigi P, Kundi J, Ivivi R, Tandrapah T, Bjorge S, et al. Epidemic malaria in the highlands of Papua New Guinea. Am J Trop Med Hyg 2005 May;72(5):554-60.

(18) Mueller I, Ousari M, Yala S, Ivivi R, Sie A, Reeder JC. The epidemiology of malaria in the Papua New Guinea highlands: 4. Enga Province. P N G Med J 2006 Sep;49(3-4):115-25.

(19) Genton B, al-Yaman F, Beck HP, Hii J, Mellor S, Rare L, et al. The epidemiology of malaria in the Wosera area, East Sepik Province, Papua New Guinea, in preparation for vaccine trials. II. Mortality and morbidity. Ann Trop Med Parasitol 1995 Aug;89(4):377-90.

(20) Genton B, al-Yaman F, Beck HP, Hii J, Mellor S, Narara A, et al. The epidemiology of malaria in the Wosera area, East Sepik Province, Papua New Guinea, in preparation for vaccine trials. I. Malariometric indices and immunity. Ann Trop Med Parasitol 1995 Aug;89(4):359-76.

(21) Cattani JA, Tulloch JL, Vrbova H, Jolley D, Gibson FD, Moir JS, et al. The Epidemiology of Malaria in a Population Surrounding Madang, Papua New Guinea. Am J Trop Med Hyg 1986 Jan 1;35(1):3-15.

(22) Genton B, D'Acremont V, Rare L, Baea K, Reeder JC, Alpers MP, et al. Plasmodium vivax and mixed infections are associated with severe malaria in children: a prospective cohort study from Papua New Guinea. PLoS Med 2008 Jul 17;5(6):e127.

(23) Muller I, Genton B, Rare L, Kiniboro B, Kastens W, Zimmerman P, et al. Three different Plasmodium species show similar patterns of clinical tolerance of malaria infection. Malar J 2009;8(1):158.

(24) Karunajeewa HA, Mueller I, Senn M, Lin E, Law I, Gomorrai S, et al. A Trial of Combination Antimalarial Therapies in Children from Papua New Guinea. N Engl J Med 2008;359(24):2545-57.

(25) Graves P, Brabin B, Charlwood JD, Burkot T, Cattani JA, Ginny M, et al. Reduction in incidence and prevalence of Plasmodium falciparum in under-5-year-old children by permethrin impregnation of mosquito nets. Bull World Health Organ 1987;65(6):869-77.

(26) Barnes KI, Durrheim DN, Little F, Jackson A, Mehta U, Allen E, et al. Effect of artemether-lumefantrine policy and improved vector control on malaria burden in KwaZulu-Natal, South Africa. PLoS Med 2005 Nov;2(11):e330.

(27) Bhattarai A, Ali AS, Kachur SP, Martensson A, Abbas AK, Khatib R, et al. Impact of artemisinin-based combination therapy and insecticide-treated nets on malaria burden in Zanzibar. PLoS Med 2007 Nov 6;4(11):e309.

APPENDIX 1: LIST OF VILLAGES IN POST-DISTRIBUTION SURVEYS

PROVINCE	DISTRICT	VILLAGE		Date of visit	Household interviews
01 WESTERN (FLY)	02 MIDDLE FLY	SAW	SAWETA	12.02.09	30
		PIS	PISI	9.02.09	23
02 GULF	01 KIKORI	KIK	KIKORI URBAN	17.07.09	31
		IRI	IRIMUKU	14.07.09	26
	05 KEREMA	KAV	KAVAINI	6.07.09	35
		UTO	UTO	1.07.09	33
03 CENTRAL	01 ABAU	MER	MERANI	18.12.08	32
		LOU	LOUPOM	8.12.08	31
	02 RIGO	GER	GERESI	13.12.08	30
		DUB	DUBANATEBOA	16.12.08	30
05 MILNE BAY	01 KIRIWINA-GOODENOUGH	MUT	MUTAWA	20.03.09	30
		ONA	ONANEBA	17.03.09	0*
	02 SAMARAI-MURUA	DOM	DOMA	26.03.09	30
		MAA	MAGALKALONA	28.03.09	30
06 NORTHERN (ORO)	01 IJIVITARI	MAR	MARASI	16.07.09	37
		FOR	FORU	20.07.09	30
	02 SOHE	KEN	KENDATA	7.07.09	40
		MNU	MANAU	11.07.09	30
09 WESTERN HIGHLANDS	01 ANGALIMP-SOUTH WAHGI	KAM	KAMANG 2	15.11.08	22
		MIN	MINZMUL	15.11.08	21
		MAU	MT. AU	10.11.08	26
	02 BAIYER-MUL	WAI	WAINDA	20.11.08	30
		SAN	SANAP	19.11.08	30
10 CHIMBU	01 KEROWAGI-MUL	KAG	KAMBANG	19.01.09	33
		KUR	KURAGL	22.01.09	32
	06 CHUAVE	KIM	KIMOE	28.01.09	30
		MAN	MAINAMO	25.01.09	30
11 EASTERN HIGHLANDS	04 LUFA	AUN	AUNO	6.10.08	50
		MAI	MAIMAFU	14.10.08	22
	06 OBURA-WONENARA	ABO	ABONAMO	20.10.08	30
		WON	WONENARA	27.10.08	30
12 MOROBE	03 MARKHAM	WAR	WARUS	4.02.09	30
		NGA	NGARIAWANG	6.02.09	23
	04 TEWAI-SIASSI	AGO	AGO	15.06.09	34
		GIT	GITUA	16.06.09	33
13 MADANG	02 MADANG	ORD	ORD	27.01.09	30
		BAF	BAFULU	25.01.09	30
	03 BOGIA	ZOG	ZOGARI	21.01.09	30
		WAZ	WAZAMB	22.01.09	29
14 EAST SEPIK	01 ANGORAM	KAR	KARANAS	18.11.08	29
		ORE	OREMAI	21.11.08	31
	02 YANGORU-SAUSSIA	PAN	PANPANIA	13.11.08	30
		WIA	WIAMUNGU	9.11.08	30
15 WEST SEPIK (SANDAUN)	01 AITAPE-LUMI	SIA	SIAUTE NO. 2	28.11.08	30
		TAB	TABALE	6.12.08	24
	06 NUKU	SUR	SURIMORTA	4.12.08	30
		YAM	YAMBIL	3.12.08	29
16 MANUS	01 MANUS	ROS	ROSSUN	3.03.09	30
		WAB	WARAMBEI	5.03.09	30
17 NEW IRELAND	02 KAVIENG	BUT	BUTEI	16.03.09	33
		LAV	LAVOLAI	18.02.09	30
	03 NAMANTANAI	KAB	KABIRARA	21.03.09	34
		BAN	BANAM	24.03.09	34

PROVINCE	DISTRICT	VILLAGE		Date of visit	Household interviews
18 EAST NEW BRITAIN	01 KOKOPO	BIR	BIRAR	6.04.09	30
		VUN	VUNABAUR	8.04.09	30
	02 GAZELLE	NAP	NAPAPAR NO. 4	2.04.09	29
		NAM	VUNAMARITA	4.04.09	30
19 WEST NEW BRITAIN	02 KANDRIAN-GLOUCESTER	SIM	SIMIMLA	19.06.09	33
		KUL	KURIL	21.06.09	28
	03 TALASEA	EWA	EWASSE	11.06.09	35
		BNL	BANAULE	15.06.09	31
20 BOUGAINVILLE (NORTH SOLOMONS)	01 NORTH-BOUGAINVILLE	SAP	SAPANI	6.05.09	34
		VOG	VAGOGO	9.05.09	36
	03 CENTRAL BOUGAINVILLE	NUP	NUPATORO 2	11.05.09	35
		TAV	TAVIDUA	13.05.09	30
				TOTAL	1958

*All data from Onaneba village in Milne Bay was lost by the airline during transport between Losuia and Alotau.

APPENDIX 2: DATES OF LLIN DISTRIBUTION

Province	District	Dates of LLIN distribution
GFATM Grant Year 1		
Central	Abau	10/07/05 - 23/07/05
East New Britain	Kokopo	25/07/05 - 26.10.05
East Sepik	Yangoru Saussi	25/05/05 - 03/09/05
Eastern Highlands	Obura/Wonenara	22/07/05 - 31/07/05
Milne Bay	Esa'ala	21/06/05 - before 18/07/05
	Kiriwina-Goodenough	21/06/05 - before 18/07/05
New Ireland	Kavieng	01/06/05 - 28/06/05
	Namatamai	01/06/05 - 28/06/05
Northern	Ijivatari	08-09/2005
Western Highlands	Tambul/Nebilyer	9/05/05 - 01/07/05
GFATM Grant Year 2		
Chimbu	Karimui/Nomane	01/08/06 - 29/09/06
	Kerowagi	15/12/05 - 27/05/06
East New Britain	Rabaul	31/05/06 - 30/06/06
	Gazelle	22/05/06 - 30/06/06
East Sepik	Wewak	Started 05/03/07
Eastern Highlands	Lufa	08-09/2007
	Okapa	18/05/06 - 08/07/06
Gulf	Kerema	21/08/06 - 10/09/06
Madang	Bogia	06/08/06 - 14/08/06
Manus	Manus	26/08/06 - 16/09/06
Milne Bay	Samarai Murua	
North Solomons	Central Bougainville	06/2006 – 03/2007
	South Bougainville	06/2006 – 03/2007
	North Bougainville	06/2006 – 03/2007
Northern	Sohe	03 – 05/2007
West New Britain	Kandrian Gloucester	06 – 07/2006
	Talasea	29/06/06 - 24/07/09
West Sepik	Aitape/Lumi	12/09/06 - 05/10/06
GFATM Grant Year 3		
Central	Rigo	
	Kairuku - Hiri	
Chimbu	Gumine	Started 06/2009
	Chuave	Started 06/2009
East New Britain	Pomio	
East Sepik	Maprik	18/03 – 02/04/2008
	Angoram	
Eastern Highlands	Henganofi	17-30/07/2008
	Goroka	15/03 – 28/04/2008
Gulf	Kikori	13/03 – 04/04/2008
Madang	Rai Coast	
	Madang	
Milne Bay	Alotau	10-11/2007
Morobe	Tewae/Siassi	06-09/2008
	Markham	06-09/2008
West Sepik	Nuku	
	Vanimo/Green River	Started 04/2008
Western Highlands	Dei	03-05/2008
	North Wahgi	03-05/2008
	Mul/Baiyer	03-05/2008
	Anglimp/South Wahgi	03-05/2008
Western	Middle Fly District	

NB: Not all listed provinces and districts were surveyed

APPENDIX 3: LIST OF SURVEYED HEALTH FACILITIES

Province	District	Health Facility	HF Type	Operating agency	Date of visit
01 WESTERN (FLY)	MIDDLE FLY	AWABA SC	SC	M	9.02.09
	SOUTH FLY	WIPIM	HC	G	21.04.09
		KURU AID POST	AP	G	16.04.09
02 GULF	KIKORI	KIKORI	DH	M	17.07.09
	KEREMA	MALALAUA	HC	G	30.06.09
		KAINTIBA	HC	G	8.07.09
03 CENTRAL	ABAU	IRUNA HF	HC	M	7.12.08
		KUPIANO HF	HC	G	20.12.08
	RIGO	KWIKILA H/C	HC	G	12.12.08
05 MILNE BAY	KIRIWINA-GOODENOUGH	MUTAWA	AP	G	20.03.09
		KADUAGA	AP	G	17.03.09
	SAMARAI-MURUA	SIDEIA CATHOLIC/M	HC	M	26.03.09
		MAGALKALONA	AP	G	28.03.09
06 NORTHERN (ORO)	IJIVITARI	TUFI HEALTH CENTRE	HC	G	15.07.09
		ST. MARGRETS H/CENTRE, FORU	HC	M	22.07.09
	SOHE	MANAU H/CENTRE	HC	M	11.07.09
		SAIHO HEALTH CENTRE	SC	G	7.07.09
09 WESTERN HIGHLANDS	ANGALIMP-SOUTH WAHGI	MT. AU HEALTH CENTRE	SC	G	10.11.08
		MINJ HEALTH CENTRE	HC	G	17.11.08
	BAIYER-MUL	TINSLEY D/HOSPITAL	DH	M	17.11.08
	JIMI	TABIBUGA	HC	G	14.05.09
		TSINGOROPA	AP	G	7.05.09
10 CHIMBU	KEROWAHGI-MUL	KENDINE H/C	HC	M	19.01.09
		MUNDE	SC	G	22.01.09
	CHUAVE	MOVI HEALTH CENTRE	SC	M	27.01.09
		CHUAVE HEALTH CEMTRE	HC	G	24.01.09
11 EASTERN HIGHLANDS	LUFA	MAIMAFU H/C	HC	G	15.10.08
		LUFA HEALTH CENTRE	HC	G	9.10.08
	OBURA-WONENARA	WONENARA	HC	G	27.10.08
		KASSAM HEALTH CENTRE	HC	M	21.10.08
12 MOROBE	FINSCHAFEN	BRAUN MEMORIAL HOSPITAL	H	M	12.06.09
		GAGIDU	UC	G	9.06.09
	BULOLO	MUMENG HEALTH CENTRE	HC	G	18.02.09
		GWASAK	AP	G	14.02.09
		BUANG	SC	G	15.02.09
	MARKHAM	SIRASIRA	AP	M	6.02.09
	TEWAI-SIASSI	GITUA	AP	G	16.06.09
		WANDOKA	AP	G	16.06.09
13 MADANG	USINO-BUNDI	SAUSI	SC	M	21.12.08
	MADANG	BAU AID POST	AP	G	20.01.09
		DANBEN	DC	G	26.01.09
	BOGIA	BOGIA	HC	G	21.01.09
		WAZAMB	AP	G	22.01.09

Province	District	Health Facility	HF Type	Operating agency	Date of visit
14 EAST SEPIK	YANGORU-SAUSSIA	KUBALIA	HC	G	10.12.08
		SOSOYA	SC	M	10.12.08
15 WEST SEPIK (SANDAUN)	TELEFOMIN	YAPSIE HEALTH CENTRE	HC	M	8.08.09
	AITAPE-LUMI	LUMI	HC	G	5.12.08
		PES	SC	M	29.11.08
	NUKU	WASSISI	SC	M	4.12.08
		NUKU	DH	G	30.11.08
16 MANUS	MANUS	LORENGAU HOSPITAL	H	G	4.03.09
		WARAMBEI	AP	G	6.03.09
17 NEW IRELAND	KAVIENG	LAMUSMUS AID POST	AP	G	18.03.09
	NAMANTANAI	LIPEK SUB H/CENTRE	SC	G	21.03.09
		BANAM	AP	G	24.03.09
18 EAST NEW BRITAIN	KOKOPO	TAPO	SC	G	6.04.09
		MOPE	AP	G	6.04.09
	GAZELLE	VUNAMARITA	AP	G	31.03.09
19 WEST NEW BRITAIN	KANDRIAN-GLOUCESTOR	AKA SUB H/CENTRE	SC	G	19.06.09
		AKINUM	AP	G	24.06.09
	TALASEA	BANAULE AID POST	AP	M	15.06.09
		EWASSE	HC	G	11.06.09
20 BOUGAINVILLE (NORTH SOLOMONS)	NORTH BOUGAINVILLE	GAGAN HELATH CENTRE	HC	M	5.05.09
		HANTOA HEALTH CENTRE	HC	G	7.05.09
	CENTRAL BOUGAINVILLE	WAKUNAI	HC	G	10.05.09
		ARAWA H/C	HC	G	13.05.09

HC - Health Centre, SC - Sub-Health Centre, UC - Urban Clinic, DC - Day Clinic, DH - District Hospital, H – Hospital
M - Mission/church, G - Government

APPENDIX 4: PROVINCIAL SUMMARY REPORTS

Summary reports for each province, including villages covered by surveys before (Sentinel Sites) and after the LLIN distribution.

01 WESTERN (FLY)
01 WESTERN (FLY) – SENTINEL SITE WIPIM
02 GULF
03 CENTRAL
05 MILNE BAY
06 NORTHERN (ORO)
09 WESTERN HIGHLANDS
09 WESTERN HIGHLANDS – SENTINEL SITE TABIBUGA
10 CHIMBU
11 EASTERN HIGHLANDS
12 MOROBE
12 MOROBE – SENTINEL SITE BULOLO
12 MOROBE – SENTINEL SITE FINSCHHAFEN
13 MADANG
14 EAST SEPIK
14 EAST SEPIK – SENTINEL SITE DREIKIKIR
15 WEST SEPIK (SANDAUN)
15 WEST SEPIK (SANDAUN) – SENTINEL SITE YAPSIE
16 MANUS
17 NEW IRELAND
18 EAST NEW BRITAIN
19 WEST NEW BRITAIN
20 BOUGAINVILLE (NORTH SOLOMONS)