NATIONAL MALARIA CONTROL PROGRAMME EVALUATION

PAPUA NEW GUINEA MALARIA INDICATOR SURVEY 2016-2017: MALARIA PREVENTION, INFECTION, AND TREATMENT

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EXECUTIVE SUMMARY

Background

Malaria has been endemic throughout Papua New Guinea (PNG) with the exception of highland areas over 1600 m altitude where low temperatures prevent stable transmission. The vision expressed in the National Malaria Strategic Plan (2014-2018) is "a substantial and sustained reduction in the burden of malaria in the near term (2014-2018) and mid-term (2019-2024), and the elimination of malaria in the long term (from 2025 onward)". In the frame of the Asia Pacific Leaders Malaria Alliance (APLMA), the PNG government envisages a malaria-free country by 2030.

With financial support from The Global Fund to Fight AIDS, Tuberculosis and Malaria, the PNG National Malaria Control Program (NMCP) has distributed long-lasting insecticidal nets (LLIN) country-wide since 2004, scaled-up malaria rapid diagnostic tests (mRDT) and artemisinin-based combination therapy at health facilities since late 2011, and implemented home-based management of malaria programmes in selected areas of the country. Behaviour change campaigns supported the roll-out of preventative and curative interventions.

Methods

In the frame of a comprehensive evaluation of the NMCP, the Papua New Guinea Institute of Medical Research (PNGIMR) conducted a country-wide Malaria Indicator Survey between September 2016 and July 2017 to assess the population coverage of malaria control interventions and the prevalence of malaria infection at national and regional levels. The survey was carried out in 102 villages (18 provinces) covering 2,743 households and 15,117 individuals. A total of 11,358 blood samples were collected for diagnosis of malaria by light microscopy.

Results

Across PNG, 80.1% of all households owned at least one LLIN and 66.7% of the population had access to an LLIN. A total of 51.1% of the household members slept under a LLIN the night before the survey. Among children <5 years, 59.5% slept under a LLIN increasing to 72.0% in households that owned at least one LLIN. Among pregnant women (15-49 years), 59.6% slept under a LLIN increasing to 70.5% if they lived in a household owning at least one LLIN. LLIN ownership and use have remained largely unchanged since 2010/11. Only 8.0% of household heads reported having received information on malaria in the past three months, mostly from health workers. Other sources of information were rarely mentioned.

Below 1600 m altitude, 7.1% of the population was infected with malaria parasites, in highland areas at 1600 m and above, only 0.9%. Infections with *P. falciparum* were more common than infections with *P. vivax*. In children <5 years of age in villages <1600 m altitude, 9.5% were infected with malaria parasites, while no malaria infections were found in children in villages at 1600 m and above. The provinces with the highest prevalence values

were Madang (16.0%), Milne Bay (10.8%), East Sepik (8.8%), New Ireland (8.7%), and Sandaun (7.9%). While in Madang and East Sepik Provinces almost all surveyed villages had >10% prevalence in adults and similar values in young children (up to 57.7% in one Madang village), the other lowlands provinces had pockets of high prevalence as well as villages with infections only in older children and adults, and villages with no infections at all. In the Highlands Region, malaria infected individuals were found in only three villages, where none of the infections was in children, suggesting importation of infections rather than local transmission. Compared to the previous survey in 2013/14, there has been a massive resurgence in malaria across PNG.

A recent fever was reported by 3.6% of all household members and 1.3% had acute fever on the day of the survey. Fever was most common in young children. Anaemia was detected in 62.5% of all household members and 3.5% had severe anaemia. Anaemia was less common in the Highlands regions and decreased with age. Of all children 2-9 years of age, 1.5% had an enlarged spleen (splenomegaly), most frequently in the provinces of Sandaun (17.8%), New Ireland (3.8%), Madang (2.5%) and Gulf (2.5%).

For 42.9% of recent fever cases in the general population and for 45.3% in children <5 years, treatment was sought outside the person's home. The most common source of treatment were health facilities (40.6% in the general population, 44.5% in children <5 years). The most frequently cited reason for not attending a health facility included long distance to the nearest facility (in combination with a lack of money for transport or medication, and a lack of medicines or poor quality of care at the facility), a perceived lack of severity of the illness and reliance on home treatment. A diagnostic test was performed in 22.6% cases in the general population and in 24.8% of the cases in children <5 years. The most commonly used drugs were antipyretics (29.6%) and antibiotics (20.2%). An antimalarial was taken by 16.5% of the fever cases and by 13.4% of children <5 years with a recent fever. The most frequently used antimalarials were the first-line treatment artemether-lumefantrine (13.9%), followed by artemether or artesunate injections (13.3%) and primaquine (12.7%). Use of artemisinin monotherapies was rarely reported. Artemether-lumefantrine was used by 85.3% of reportedly test-positive persons, and by 89.6% of test-positive children <5 years.

Targets and results of key indicators used in the evaluation of the Global Fund support to the PNG NMCP are listed in the table on the following page. Maps depicting LLIN coverage and malaria prevalence by province in four consecutive surveys are shown on subsequent pages.

Conclusion

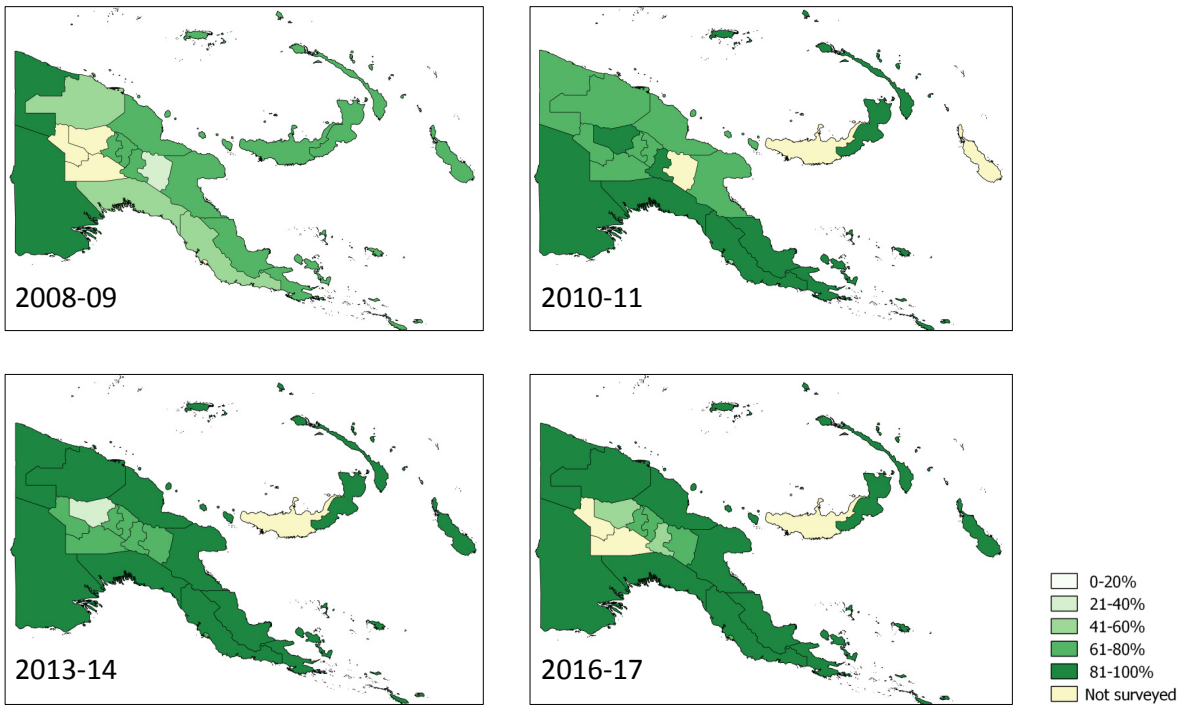
The historical achievement of the PNG national malaria control program, i.e. the reduction of malaria prevalence to <1% by 2013/14, has suffered a major setback in the last three years. Results from this and other surveys conducted by PNGIMR suggest that, in general, intervention coverage has plateaued at best. In consideration of the observed trend, the longer-term goal of malaria elimination from PNG by 2030 is less likely now than it was at the time the National Malaria Strategic Plan (2014-2018) was drafted. The current resurgence in malaria is likely to worsen unless malaria control is re-intensified without delay, inclusive of the provision of sufficient funding for vector control, diagnosis, treatment, behaviour change campaigns and operational research.

Table of Global Fund Performance Framework indicators, 2017 targets, and survey values.

Global Fund Indicator	Target	Survey result
Parasite prevalence: Proportion of children aged 6-59 months with malaria infection (I-5)	**2%**	**9.5%**
Proportion of population that slept under an insecticide-treated net the previous night (O-1a)	**60%**	**51.1%**
Proportion of children under five years old who slept under an insecticide-treated net the previous night (O-1b)	**65%**	**59.5%**
Proportion of pregnant women who slept under an insecticide-treated net the previous night (O-1c)	**65%**	**59.6%**
Proportion of population with access to an LLIN within their household (O-2)	**70%**	**66.7%**
Proportion of population using an LLIN among the population with access to an LLIN (O-3)	**82%**	**76.6%**
Proportion of households with at least one insecticide-treated net (O-5)	**85%**	**80.1%**
Proportion of children under five years old with fever in the last two weeks for whom advice or treatment was sought	**65%**	**45.3%**

Trends in LLIN ownership, by province, Papua New Guinea

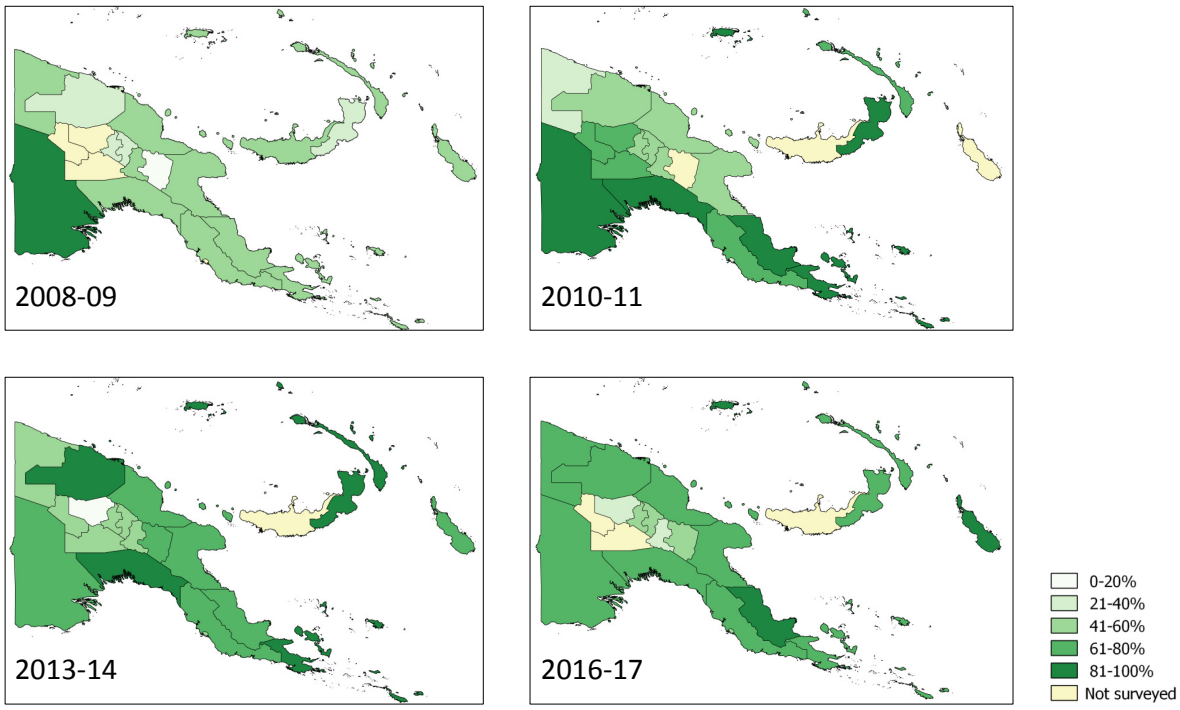
Percent of households owning at least one LLIN.



Data source: PNGIMR surveys.

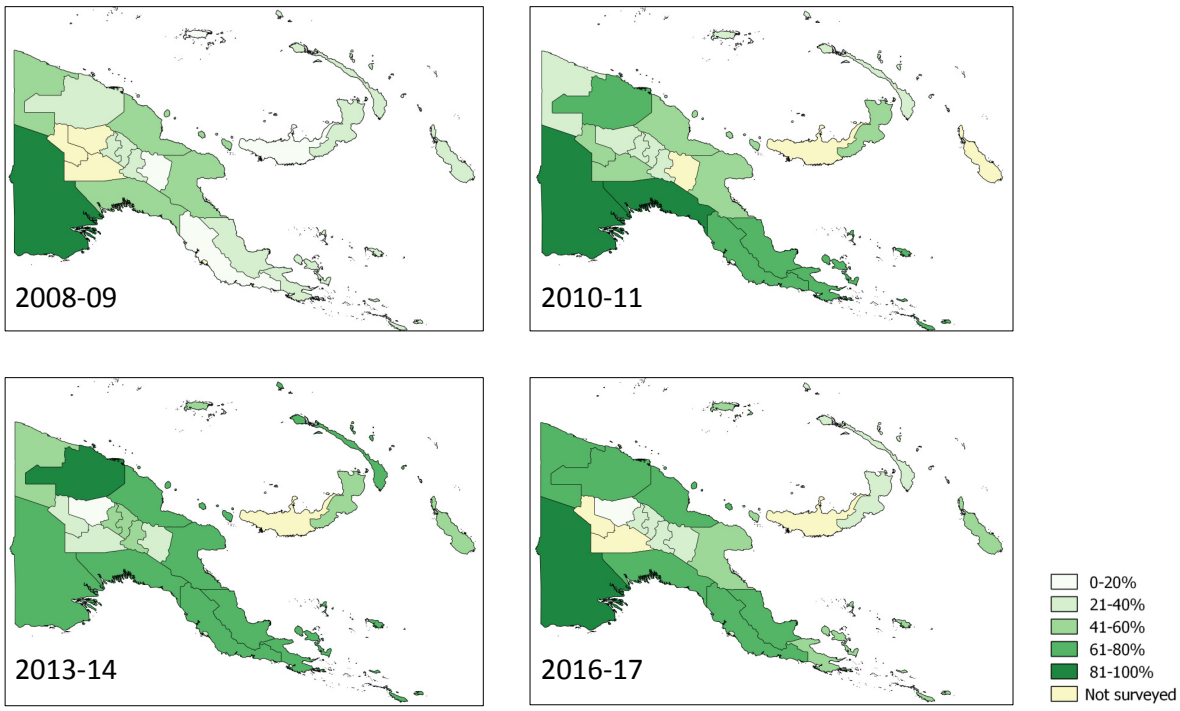
Trends in LLIN access, by province, Papua New Guinea

Percent of persons with access to an LLIN within their household.



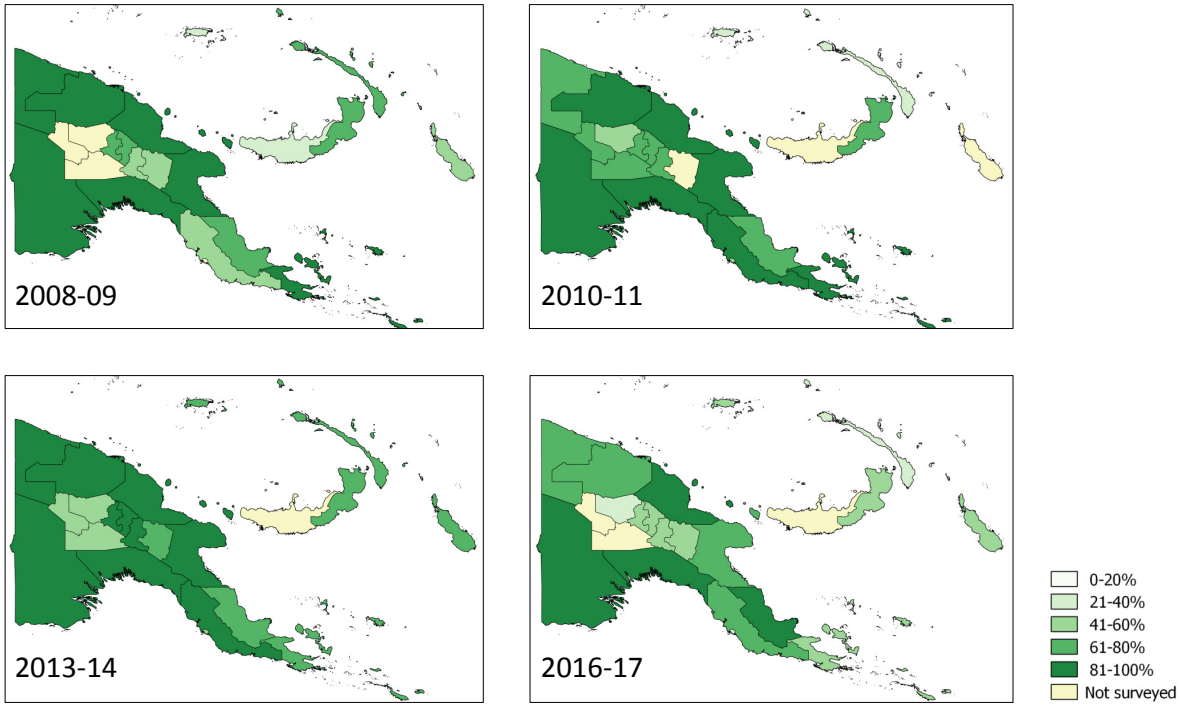
Data source: PNGIMR surveys.

Trends in LLIN use, by province, Papua New Guinea
Percent of persons using a LLIN last night



Data source: PNGIMR surveys.

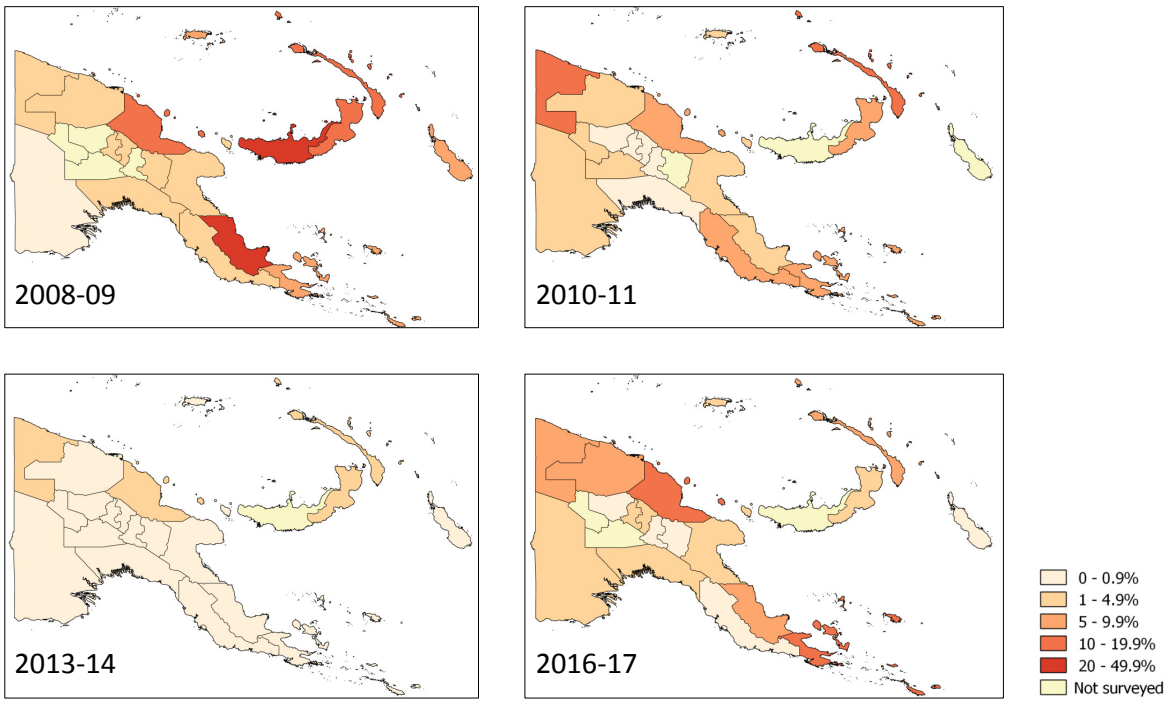
Trends in LLIN use among those with access, by province, Papua New Guinea
Percent of persons with access to LLIN using a LLIN last night



Data source: PNGIMR surveys.

Trends in malaria prevalence, by province, Papua New Guinea

Percent of persons infected with *Plasmodium* parasites (any species)



Data source: PNGIMR surveys.

CONTENTS

1 INTRODUCTION

1.1 The PNG National Malaria Control Program

Historically, malaria has been endemic throughout Papua New Guinea (PNG) with the exception of highland areas over 1600 m altitude where low temperatures prevent stable local transmission, though occasional epidemics occur [1, 2]. Four human pathogenic malaria parasites occur in PNG (*Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium malariae* and *Plasmodium ovale*), transmitted by a variety of *Anopheles* mosquitoes that are adapted to distinct ecological niches [3].

The PNG National Malaria Control Program (NMCP) has been financially supported by The Global Fund to Fight AIDS, Tuberculosis and Malaria (The Global Fund) since 2004. National distribution campaigns provided long-lasting insecticidal nets (LLIN) at the household level since 2004 and malaria rapid diagnostic tests (mRDT) and artemisinin-based combination therapy (ACT) have been scaled up at health facilities throughout the country since late 2011 [4, 5]. In selected areas of the country, home-based management of malaria programmes were implemented and behaviour change campaigns supported the roll-out of preventative and curative interventions.

Since the inception of Global Fund support, the PNG NMCP has been operating as a partnership of various organizations, including the National and Provincial Departments of Health, non-governmental organizations, the private sector and academic and research institutions. Under the funding arrangement ending in December 2017, the Global Fund supported two Principal Recipients (PR), namely Rotarians Against Malaria (RAM), responsible for the distribution of LLIN, and Population Services International (PSI), responsible for implementing the home-based management of malaria programme and nation-wide behaviour-change communication.

The vision of the current National Malaria Strategic Plan (2014-2018) is “a substantial and sustained reduction in the burden of malaria in the near term (2014-2018) and mid-term (2019-2024), and the elimination of malaria in the long term (from 2025 onward), when existing and new tools in combination with strengthening of health systems will make national elimination feasible”. In the frame of the Asia Pacific Leaders Malaria Alliance (APLMA), the PNG government envisages a malaria-free PNG by 2030 [6].

A comprehensive monitoring and evaluation component has been established as part of the Global Fund grants. The Papua New Guinea Institute of Medical Research (PNGIMR) has been responsible for the overall independent evaluation of the outcomes and impact of the NMCP and to provide scientific evidence of the country's progress in scaling up control measures and reducing the malaria burden. The PNGIMR evaluation assesses key outcome and impact indicators against targets defined in the Global Fund grant performance frameworks. It also aims to provide accurate, up-to-date information on different aspects of the changing malaria epidemiology in PNG. The evaluation plan developed by the PNGIMR combines several complementary data collection mechanisms aiming to simultaneously assess changes in intervention coverage as well as trends in malaria morbidity, mortality, and transmission [7].

Epidemiological studies conducted by the PNGIMR have demonstrated that the financial support from the Global Fund has allowed PNG to make significant progress in malaria control, leading to an unprecedented decline in malaria between 2004 and 2014. Prevalence of malaria infection in villages below 1600 m altitude decreased from 11% in 2008/09 to less than 1% in 2013/14 [8]. Incidence of test-confirmed cases in sentinel surveillance sites dropped by 85-90% immediately after the first country-wide distribution of LLIN and National Health Information System (NHIS) data confirm a decline after the scale up of interventions; however, the latter is more difficult to interpret due to the scale-up of mRDTs over the same period [9, 10].

1.2 Objectives of the Survey

The Malaria Indicators Survey 2016-2017 aimed to assess population coverage of malaria control interventions and prevalence of malaria infection in all age groups against targets in the Global Fund grant performance framework. The survey was designed to provide national and regional estimates of results that can be compared with results from surveys conducted in previous years and to provide provincial level estimates for Momase and Islands Regions. The sample size was increased in the relevant provinces to improve the accuracy of the provincial estimates.

1.3 Map of PNG

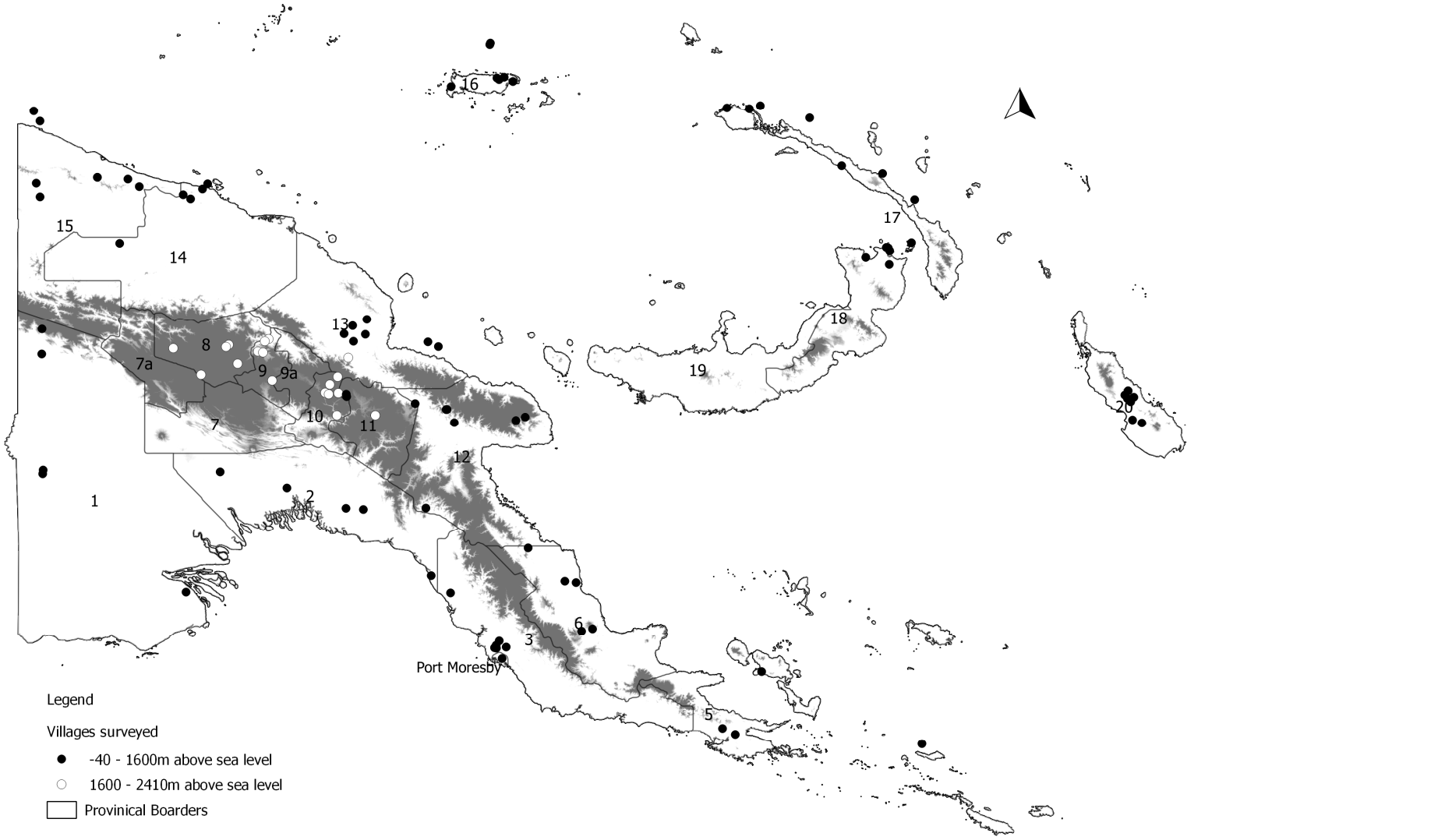


Figure 1: Map of Papua New Guinea showing provinces and approximate location of survey villages.

2 METHODOLOGY

2.1 Sample design

The sampling procedure was consistent with that of the national household surveys previously conducted in 2010/11 and 2013/14 in the frame of the national malaria control program evaluation [4, 8]. Selection of villages for the survey was based on a province-stratified multi-stage sampling approach using the 2000 National Census database of villages ("census units") as sampling frame[1]. Per province, a random sample of five villages was selected from provinces in Southern and Highlands Regions and seven villages from provinces in Momase and Islands Regions using Stata 11.0 software (Stata Corp LLP, College Station, TX, USA). For each province, an equal number of villages were sampled as back-up, excluding the originally sampled villages. Whenever a village was inaccessible due to major logistic or security constraints, it was substituted with a nearby back-up village. Within each selected village, a maximum of 30 households were then randomly sampled from a census of households established by the survey team leader upon arrival in the village and in consultation with local village representatives. A random number table was used for sampling the households. Within each selected household, an adult member acting as the household head, women aged 15-49 years and parents of recently sick children were eligible for interviews, while all household members were eligible for providing a finger-prick blood sample.

2.2 Questionnaires

Four structured electronic questionnaires were used during the survey and administered to the household head and/or other household members, as described below. Adapted from the Malaria Indicator Survey set of questionnaires [11] they included: 1) a household questionnaire, 2) a treatment seeking questionnaire, 3) a prevalence form, and 4) a women's questionnaire. Questionnaires were programmed in Open Data Kit (ODK) and administered using tablet computers. Paper copies of each questionnaire were available as back-up.

[1] 2000 was the latest census for which village-level data was accessible.

2.2.1 Household questionnaire

The household questionnaire was completed with the adult household heads of the randomly selected households. The information obtained covered the ownership and use of LLINs, exposure to behavior change messages and other interventions, alongside demographic information of each household member as well as indicators of the household's socio-economic status.

2.2.2 Treatment seeking questionnaire

The treatment seeking questionnaire was completed with household members or caregivers (in the case of persons under the age of 15 years), who reported having experienced a febrile illness in the two weeks prior to the survey. The information obtained was about the signs, symptoms and duration of the illness and subsequent treatment seeking behaviour, including sources of treatment, completion of a diagnostic test, and types of any drugs administered.

2.2.3 Prevalence form

The prevalence form was completed with every available household member. The information obtained was about treatment history (use of an antimalarial in the two months prior to the survey and any other medication at the time of survey), recent travel history and experience of fever in the past two days. In addition, consent to collect a blood sample for haemoglobin (Hb) and malaria testing was recorded alongside the results of the Hb measurement, the mRDT test result and the Hackett grade indicating the size of the spleen that was palpitated in children aged 2 to 9 years. Axillary temperature was measured by electronic thermometer and recorded. Any treatment administered by the research nurse or referral to a health facility were also recorded in the form.

2.2.4 Women's questionnaire

The women's questionnaire was administered to female members of the selected households aged between 15 to 49 years. The form was used to collect information about the total birth history of the women (including all live births and death of children) as well as coverage with Intermittent Preventive Treatment of malaria during pregnancy (IPTp).

2.3 Malaria and anaemia testing

A trained nursing officer collected a blood sample by finger-prick from each member of the selected households who was six months of age or older. The blood sample was taken from

those household members who were present at the time of the survey. From the finger-prick, one thick and one thin blood smear were prepared on the same glass slide for diagnosis of malaria by light microscopy, an mRDT (CareStart Malaria HRP2/pLDH (Pf/pan) Combo Test, Access Bio) was performed and a microcuvette sample was prepared to measure Hb levels using a handheld HemoCue Hb 201+ analyser (HemoCue, Ängelholm, Sweden). An mRDT was performed on all individuals reporting a fever in the past two days. In addition, in a subset of provinces, mRDTs were performed on all household members for a more timely assessment of prevalence[2]. All mRDT positive participants were treated by the nursing officer following the national treatment protocol [12].

Malaria diagnosis by light microscopy was performed at the PNGIMR in Madang following established procedures [13, 14]. Each slide was examined independently by two trained microscopists, each viewing a minimum of 200 thick film fields. Slides with discordant results were examined by a third senior microscopist, who was certified at World Health Organization (WHO) level 1 or 2. A slide was considered positive for malaria if judged positive by at least two microscopists.

2.4 Survey implementation procedures

The country-wide survey was carried out between September 2016 and July 2017 by three trained field teams working simultaneously at different sites. Each team consisted of at least one nursing officer, one or more scientific officers and one or two research assistants. All members of the field teams received extensive training covering project background, the survey protocol and methods, the survey instruments, and blood sample collection techniques for nursing officers who collected blood sample.

The survey was conducted in 18 provinces of PNG[3]. Two provinces were excluded due to security concerns: West New Britain where a survey team of 5 PNGIMR staff disappeared without trace and were most likely murdered in 2011 and Southern Highlands (incl. Hela) due to post-2017 election unrest.

Prior to conducting the survey in a particular province, provincial health authorities were informed of the scope of the survey, the selected sites and the timing of the survey. A local health officer was requested to accompany the survey team. Upon arrival in the survey village, the team established contact with local village leaders or councilors in order to

[2] An amendment to the original study protocol was required to perform mRDTs on all household members. As approval was granted only after the start of the survey there are no mRDT results available from the first few surveyed provinces.

[3] For practical reasons, the pre-2012 province structure was still applied in this survey, i.e. Western Highlands and Jiwaka were considered as one province and Southern Highlands and Hela were considered as one.

explain the purpose and procedures of the survey. After the community's approval to conduct the survey, with the assistance of the village leader or councilor, the team leader established a household listing and performed the random sampling of households using a random number table. Village locations and elevation above sea levels were recorded with a hand-held GPS device (Garmin). The survey teams spent on average 3 to 5 days in each village.

2.5 Data management and analysis

All data were collected electronically using the Open Data Kit (ODK) Collect application installed on tablet computers. All data were checked and finalized by the field team leader prior to submission. Completed and checked forms were then uploaded directly to the main server at the Swiss Tropical and Public Health Institute (Swiss TPH) in Switzerland using the local mobile phone network (digicel). PNGIMR investigators had unlimited direct access to the uploaded data. ODK Briefcase v1.4.9 was used to download and export datasets for analysis in Stata/IC 14.2 (StataCorp LLC, College Station, TX, USA).

Aggregated national and regional level weighted proportions with logit transformed 95% confidence limits were calculated for all coverage indicators using the survey design command set in Stata (*svy*). Sampling weights were calculated as the inverse of an observation's probability of selection. To account for the staged sampling design, the overall probability of selection was calculated as a product of the selection probabilities at each sampling stage, i.e. the probability of a village being selected within a district and 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.

Mosquito net ownership and use indicators were calculated following standard procedures [15]. The proportion of the population with access to a LLIN was calculated by dividing the number of LLIN sleeping spaces (assuming two per LLIN) by the number of people sleeping in the household and then multiplied each household observation by the number of people in the household the previous night. The "proportion of people with access using an LLIN" was calculated by dividing the number of people using an LLIN by the total population with access (derived from applying the weighted proportion with access to the total population). This approach was required as the access indicator is calculated at a household level and does not allow allocation of access to individuals [16].

Measures of the prevalence of malaria infection and morbidity were age-standardized using the standard population for Asia given by the International Network for the Demographic

Evaluation of Populations and Their Health (INDEPTH) [17]. To account for stratified sampling, national estimates were weighted, as described above. Considering the close association of altitude and malaria transmission, and to ensure comparability with previous surveys, prevalence measures are presented separately for villages below 1600 m altitude (national estimate) and for villages at 1600 m altitude and above.

Splenomegaly in children aged 2-9 years was defined as palpable spleen (Hackett grade 1-5) and anaemia following WHO definitions including age-specific cut-offs and altitude correction [18].

Binary variables were compared using $\chi 2$ tests and logistic regression, and non-normally distributed variables were compared using the non-parametric Mann–Whitney U test.

2.6 Ethical considerations

Prior to commencing work in a selected village, a community meeting was called to communicate the purpose of the study and questions were answered at individual and community levels. Villagers were informed about the confidentiality of the data, the purpose of the finger prick blood samples collected and permission to conduct the survey in the particular village was sought.

Participation in this survey was voluntary. All selected households were consented individually prior to participation. Written informed consent was obtained from the household head and verbal informed consent was obtained from each interviewee and from individuals or caretakers prior to the collection of a blood sample. Household members who refused to be finger-pricked were only administered the accompanying questionnaire.

Study participants diagnosed with malaria were offered treatment according to national guidelines free of charge. As a community service, PNGIMR nursing officers also provided treatment for minor ailments or referral advice to the general public in the survey villages.

The study protocol was approved by the Institutional Review Board of the PNGIMR (IMR IRB No. 1512) and the Medical Research Advisory Committee of the National Department of Health (MRAC No. 15.21).

3 RESULTS

3.1 Survey sample characteristics

This chapter presents details of the survey population by location and basic demographic and socioeconomic characteristics of households.

Information on the socioeconomic situation of the survey households provide context for interpreting demographic and health indicators, can furnish an approximate indication of the representativeness of the survey and hence help in the extrapolation of survey findings. Specific socioeconomic characteristics are useful for understanding the factors that affect use of health services and other health behaviours related to malaria control. In addition, socioeconomic indicators shed light on the general living conditions of the population of PNG.

The socioeconomic indicators presented in this report include information on the sources of drinking water, sanitation, housing characteristics, ownership of durable goods, and composition of the household population.

3.1.1 Survey sample

The survey was carried out in 102 villages located in 18 provinces. Eighty-two (80.4%) villages were located below 1200 m altitude, 2 (2.0%) villages between 1200 and 1599 m, and 18 (17.7%) villages at 1600 m or above (Figure 1). Nine (11.0%) villages in the lowest altitude category were considered to be part of an urban area.

The survey was completed in 2,743 households comprising a total *de jure* population of 15,535 usual residents. The *de facto* population of individuals present in the household the night prior to the survey amounted to 15,117.

> The *de facto* population includes all persons who stayed in the selected households the night before the interview (whether usual residents or visitors). The *de jure* population are all persons who are usual residents of the selected households, whether or not they stayed in the household the night before the interview. All calculations are based on the de facto population, unless specified otherwise.

Of the *de facto* population, 13.9% were children below 5 years of age and 50.4% were female. The survey also included 136 women aged 15-49 years who reported to be pregnant and 272 household members (incl. 73 children <5 years) who had experienced a febrile illness episode in the past 2 weeks. A total of 11,358 blood samples were collected for diagnosis of malaria by light microscopy.

The distribution of surveyed households and of the population by location, altitude, age group, and sex is shown in Table A1, Appendix A.

The population pyramid in Figure 2 shows the study population distribution by sex and by 5-year age groups. The broad base of the pyramid is indicative of a young population, typical of developing countries, with a high fertility rate and low life expectancy. The similar length of the lowest two age groups could suggest a recent reduction in birth rate or a recent increase in child mortality. There appears to be a certain imbalance in the study population between males and females in children (more males) and young adults (more females).

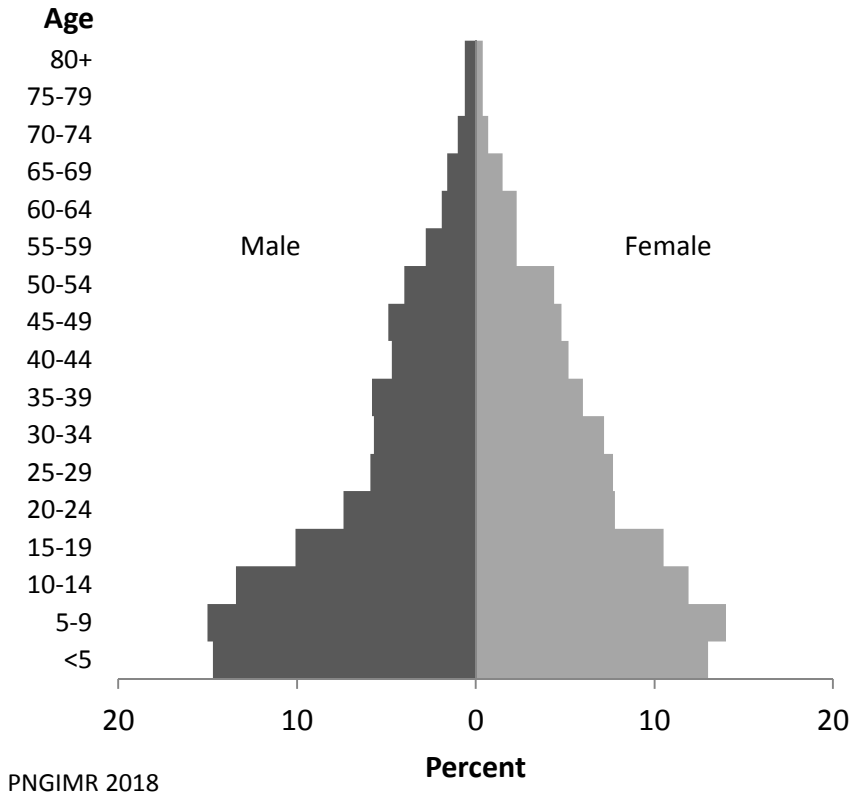


Figure 2. Population pyramid.
Percent distribution of the household population, by sex and five-year age group

3.1.2 Water and sanitation

Improved sources of drinking water include piped water, public taps, standpipes, protected wells and springs, boreholes, and rainwater.

Across PNG, only 40.3% of households used an improved source of drinking water, while 59.1% of households relied on surface water such as rivers, streams, lakes and ponds, on open wells. Urban and rural households relied on different sources of drinking water; 53.5% of households in urban settings had piped water available in their house or in the neighbourhood compared to 11.6% of rural households. Conversely, 58.3% of rural households used surface water for drinking compared to 7.4% of urban households (Table 1). Unimproved sources of drinking water, such as untreated surface water, are prone to contamination with organic and chemical pollutants originating for example from human and animal wastes or from pesticide use in agriculture.

Improved toilet facilities include toilets of the following types: own or shared pit latrines with slab, own or shared flush toilet, and composting toilets[4].

Across PNG, the most common toilet facilities were open pit latrines, which were used by 55.7% of households. Open defecation was still practiced in 16.5% of households. Urban households had better access to own flush toilets than rural households (43.0% vs. 3.3%) (Table 2).

Table 1. Household drinking water

Percent distribution of households by source of drinking water, according to location, Papua New Guinea, 2016-2017

	Households		
Source of drinking water	Rural	Urban	Total
Improved source			
Piped into dwelling	4.1	30.5	6.7
Piped into neighbourhood / public tap	7.5	23.1	9.0
Protected well (public/private)	1.4	0.0	1.3
Water tank/rainwater	22.1	35.2	23.4
Unimproved source			
Open well (public/private)	6.1	2.8	5.8
Surface water (river, stream, lake, pond, etc.)	58.3	7.4	53.3
Other source	0.5	1.1	0.5
Total	100	100	100
Number	2,493	250	2,743

[4] Other surveys usually consider any type of shared toilets as unimproved sanitation.

Table 2. Household sanitation facilities

Percent distribution of households by type of toilet facilities, according to location, Papua New Guinea, 2016-2017

	Households		
Type and location of toilet/latrine facility*	Rural	Urban	Total
Improved sanitation			
Shared pit latrine with slab	1.1	2.9	1.2
Own pit latrine with slab	3.6	3.6	3.6
Shared flush toilet	0.5	6.0	1.0
Own flush toilet	3.3	43.0	7.2
Unimproved sanitation			
Shared open pit latrine	15.1	17.3	15.3
Own open pit latrine	58.9	26.4	55.7
Closet over sea/river	0.5	0.0	0.4
Open defecation (no facility/bush/field)	18.2	0.9	16.5
Number of households/population	2,493	250	2,743

* Multiple answers were allowed

Globally, unsafe water and inadequate sanitation and hygiene contribute to the deaths of some 842,000 people every year, representing 58% of deaths caused by diarrhoea. About 361,000 of these deaths occur in children aged under 5 years [19]. While 91% of the world's population are by now using an improved source of drinking water [20], the majority of people in PNG appear to belong to the 663 million people worldwide who still lack access to improved water sources. The majority of rural households still lack access to improved sanitation facilities that prevent likely contact with human waste and reduce the transmission of typhoid, cholera and other diseases. The United Nation's Sustainable Development Goal 6 is to ensure access to safe water and sanitation for all [21].

3.1.3 Housing characteristics and household possessions

The survey collected data on the characteristics of houses people live in, such as access to electricity, flooring, wall and roofing material, and types of fuel used for cooking. The information on these characteristics, along with other information on the ownership of household durable goods provides an indication of the socioeconomic status of households and of the living conditions of the population. Some specific information may be relevant for other health indicators.

The majority of households (86.5%) had no access to electricity through the power grid or from a generator (Table 3). The most commonly used method of lighting in rural areas was

solar power (38.3%) or lamps/lanterns powered by batteries or fuel/kerosene (42.4%). The majority of urban households had access to electricity (66.2%).

Firewood, coconut shells, and similar materials were the predominant fuel used for cooking in urban and rural areas (93.5%). Electricity and gas were primarily used in urban areas (25.9% and 11.1%, respectively). Exposure to smoke produced from solid fuels is a potential health hazard.

The majority of houses across PNG are constructed with unprocessed natural materials. Floors and outer walls of most houses in rural areas are made from wood, palm leaves, bamboo or different types of grass. Processed materials such as polished wood, plywood, masonite, cement, tiles, bricks or iron sheet are primarily found as building materials in urban areas. Almost all (90.4%) houses in urban areas have corrugated iron roofs, while in rural areas, roughly equal proportions have roofs made of thatched grass (29.3%), palm/sago leaves (36.3%), and corrugated iron (34.1%).

Table 4 provides details on possession of selected durable household goods, means of transport and livestock. The majority of households in urban and rural areas owned a mobile phone (91.9% and 59.9%, respectively). Radio and television were found primarily in urban areas; only 18.5% of rural households owned a radio and 11.6% a television (25.2% in the Islands Region). Ownership of a mobile phone, radio or television may be of practical importance for the planning of mass communication campaigns in the context of promoting malaria control intervention uptake.

Households across PNG do not generally own any means of transport. The most commonly found means of transport was a canoe/boat without motor (14.7%). In urban areas, households also owned bicycles (20.8%) and cars or trucks (17.4%). Means of transport may be important in the case of a sick household member requiring transport to a health facility. Ownership of means of land transport may in many parts of PNG be a mere function of the (non-) existence of usable roads.

The most commonly kept livestock animals were pigs (43.8%) and chickens (33.1%), both being more frequently kept by rural households. In rural households in the Highlands Region, pigs were far more commonly found than chickens (59.0% vs. 12.1%), while in the other regions, chickens were more common than pigs.

Table 3. Housing characteristics

Percent distribution of households by housing characteristics, according to location, Papua New Guinea, 2016-2017

	Households[1]		
Housing characteristic	Rural	Urban	Total
Lighting			
None	1.1	0.0	1.0
Candle	1.2	0.1	1.1
Lantern/lamp	5.0	1.2	4.7
Battery lantern	37.4	19.3	35.6
Solar power	38.3	13.1	35.9
Electricity	7.8	66.2	13.5
Open fire	3.3	0.0	3.0
Other	6.0	0.2	5.5
Total	100.0	100.0	100.0
Flooring material			
Earth/sand	26.5	8.5	24.8
Palm/bamboo/grass	41.6	7.3	38.2
Wood	22.5	47.3	24.9
Polished wood	5.5	21.2	7.0
Cement/tiles	3.9	14.9	5.0
Other	0.0	0.8	0.1
Total	100.0	100.0	100.0
Outer wall material			
Bamboo / pitpit	54.0	2.6	49.0
Sago, palm leaves	23.3	4.8	21.5
Wood	8.6	43.7	12.0
Plywood	3.4	12.8	4.3
Masonite/Fibro	5.9	20.5	7.3
Cement or bricks	0.7	1.8	0.8
Iron sheets	3.9	13.0	4.8
Other	0.1	0.9	0.2
Total	100.0	100.0	100.0
Roofing material			
Thatched grass	29.3	0.0	26.5
Sago, palm leaves	36.3	8.5	33.6
Corrugated iron	34.1	90.4	39.6
Wood planks	0.2	0.8	0.2
Other	0.1	0.3	0.1
Total	100.0	100.0	100.0
Cooking fuel			
Firewood	88.9	55.0	85.6
Small twigs/tree branches/coconut shell	8.2	6.0	8.0
Kerosene	0.1	1.3	0.2
Gas	1.3	11.1	2.2
Electricity	1.6	25.9	4.0
Other	0.0	0.6	0.1
Total	100.0	100.0	100.0
Number of households	2,493	250	2,743

[1] Weighted proportions

Table 4. Household possessions

Percentage of households possessing various household effects, means of transportation, and livestock/farm animals, according to location, Papua New Guinea, 2016-2017

Possession	Residence		Total
	Rural	Urban	
Household effects			
Radio	18.5	44.3	21.1
Television	11.6	52.1	15.5
Mobile phone	59.9	91.9	63.0
Non-mobile telephone	0.1	2.2	0.3
Refrigerator	4.5	56.7	9.6
Means of transport			
Bicycle	6.4	20.8	7.8
Motorbike	0.4	2.4	0.6
Car/truck	1.8	17.4	3.3
Dugout, canoe (without motor)	15.5	7.1	14.7
Boat with a motor	2.3	2.1	2.3
Ownership of farm animals[1]			
Chicken	34.7	18.9	33.1
Cassowaries	1.0	0.0	0.9
Goats and sheep	3.4	0.0	3.1
Pigs	47.5	9.2	43.8
Cows	0.001	0.0	0.001
Number of households	2,493	250	2,743

3.2 Malaria prevention: mosquito net coverage

This chapter provides results on the population coverage with mosquito nets, particularly long-lasting insecticidal nets (LLIN)[5]. Mosquito net ownership was assessed for all households (N = 2,743) and use was assessed for all *de facto* households members (N = 15,117).

The following targets were definded in the Global Fund grant performance framework:	
Proportion of population that slept under an insecticide-treated net the previous night (O-1a)	**60%**
Proportion of children under five years old who slept under an insecticide-treated net the previous night (O-1b)	**65%**
Proportion of pregnant women who slept under an insecticide-treated net the previous night (O-1c)	**65%**
Proportion of population with access to an LLIN within their household (O-2)	**70%**
Proportion of population using an LLIN among the population with access to an LLIN (O-3)	**82%**
Proportion of households with at least one insecticide-treated net (O-5)	**85%**

3.2.1 Mosquito net ownership

Across PNG, 81.6% (95% CI 77.9, 84.8) of households owned at least one mosquito net and 80.1% (95% CI 76.4, 83.3) at least one LLIN. The average number of nets per household was 2.6 (95% CI 2.4, 2.8) for any type of net and 2.5 (95% CI 2.3, 2.7) for LLIN. At least one LLIN per two people who stayed in the household the last night was available in 64.6% (95% CI 60.3, 68.8) of households (Table 5 & Table B1, Appendix B).

There was a significant difference in mosquito net and LLIN ownership between Southern, Momase and Islands Regions, where over 85% of households owned a LLIN, and the Highlands Region, where only 60.5% of households owned a LLIN ($P < 0.001$). Within the Highlands region, households in villages located at ≥1600 m altitude were less likely to own a LLIN than households in lower-lying villages (57.9% vs. 71.2%, $P < 0.05$, data not in table). There was no significant difference in ownership between surveyed urban and rural locations. LLIN ownership was below the national average in the Highlands provinces and NCD.

[5] All insecticide treated nets distributed through Global Fund supported campaigns are LLINs.

Table 5. Household ownership of mosquito nets

Percentage of households with at least one mosquito net (treated or untreated) and long-lasting insecticidal net (LLIN); average number of nets and LLINs per household; and percentage of households with at least one net and LLIN per two persons who stayed in the household last night, according to background characteristics, Papua New Guinea, 2016-2017

Background characteristic	Percentage of households with at least one mosquito net		Percentage of households with at least two LLIN	Average number of nets per household		Percentage of households with at least one LLIN for every two persons[1]	Number of households
	Any net	LLIN		Any net	LLIN		
Residence							
Rural	81.31	79.66	65.27	2.5	2.4	51.56	2,493
Urban	84.02	83.74	76.47	3.2	3.1	53.45	250
Region							
Southern	89.5	89.0	74.8	2.8	2.8	53.8	752
Highlands	60.5	60.5	42.9	1.4	1.4	35.5	511
Momase	93.8	90.1	79.0	3.4	3.3	61.6	739
Islands	89.1	87.7	77.1	2.9	2.8	61.8	741
	*	*	*	*	*	*	
Overall	81.6	80.1	66.4	2.6	2.5	64.6	2,743
(95% CI)	(77.9, 84.8)	(76.4, 83.3)	(61.9, 70.6)	(2.4, 2.8)	(2.3, 2.7)	(60.3, 68.8)	

[1]Calculated for persons who stayed in the household last night
*Differences between categories are statistically significant at P < 0.001

Target: The target of 85% household ownership of at least one LLIN was not reached on a national level but in 11/18 surveyed provinces. The target was missed in East Sepik and East New Britain (by a small margin) and in all surveyed Highlands provinces and NCD by a wider margin (Table B1, Appendix B).

Trend: Household ownership of nets and LLIN has remained largely stable since 2011, while the proportion of households owning one net per two people has steadily increased, indicating an increase in the number of nets in net-owning households (Figure 3).

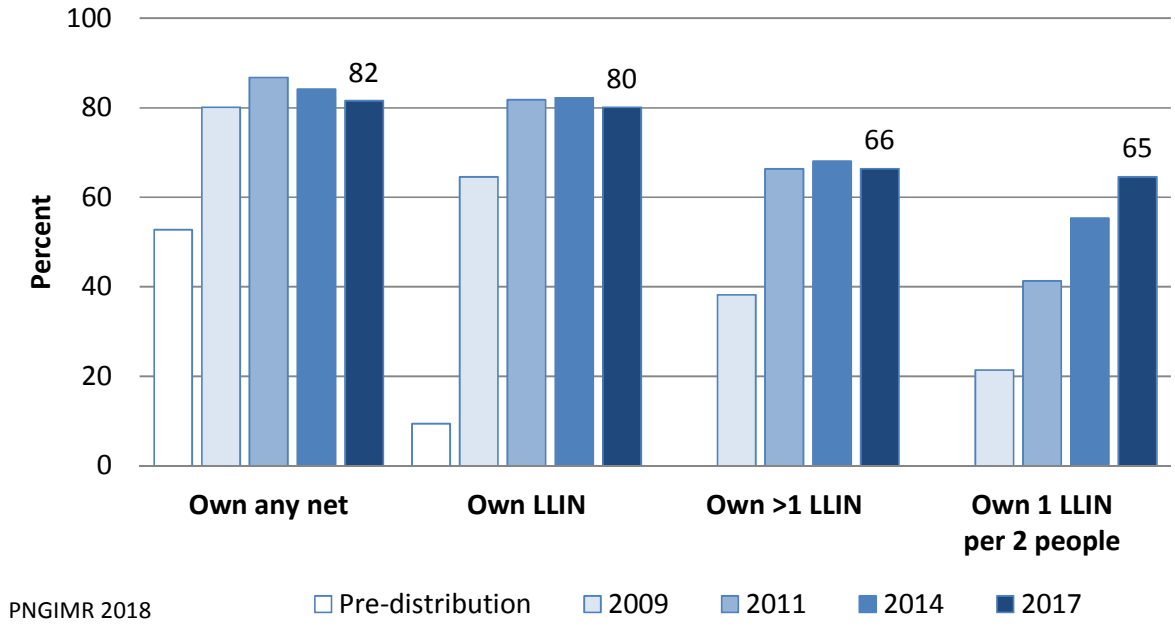


Figure 3. Trend in ownership of mosquito nets.
Pre-distribution estimate and national survey results 2009-2017. Data source: PNGIMR surveys.

3.2.2 Mosquito net access and use

In this context, access to an LLIN is defined as the percentage of the *de facto* household population who could sleep under an LLIN if each LLIN in the household was used by up to two people. For example, in a household with 10 household members and 5 nets, 100% of the members have access, whereas in a household with 10 members and 2 nets, only 40% (4 out of 10) of members have access.

Across PNG, 66.7% (95% CI 62.7, 70.7) of the population had access to an LLIN. Access was significantly lower in the Highlands (44.7%) than in the other regions ($P < 0.001$) (Table 6). Access was below the national average in all Highlands provinces and in NCD, Sandaun and East New Britain (Table B2, Appendix B). Using these numbers, an "access gap" can be calculated, reflecting the number of people requiring additional LLINs[6]. Based on the predicted 2017 population of PNG, and estimated 2.7 million people were without access to an LLIN requiring approximately 1.4 million LLIN to fill this gap (Table 7).

[6] The calculation of the "access gap" is a snapshot at one point in time and does not take into consideration new LLINs distributed and the attrition of LLINs following the date of the survey.

Table 6. Access to an LLIN

Percentage of the de facto population with access to an LLIN in the household, according to background characteristics, Papua New Guinea, 2016-2017

Background characteristic	Percentage of the de facto population with access to an LLIN[1]
Residence	
Rural	66.3
Urban	70.1
Region	
Southern	72.0
Highlands	44.7
Momase	76.3
Islands	75.3
	*
Total	66.7
95% CI	(62.7, 70.7)

[1] Percentage of de facto household population who could sleep under an LLIN if each LLIN in the household were used by up to two people.
*Difference between categories is statistically significant at P < 0.001

Table 7. Access to LLIN gap

Population with access to LLIN, "gap" of people without access, and number of LLIN required to fill the "access gap" based on two people per LLIN

Region	Population*	Percent with access to LLIN	Population with access to LLIN	Access gap	Number of LLIN required
Southern	1,650,232	72.0	1,363,923	286,309	143,155
Highlands	3,217,953	44.7	1,870,485	1,347,468	673,734
Momase	2,145,302	76.3	1,973,273	172,029	86,014
Islands	1,237,674	75.3	633,229	604,446	302,223
Total	8,251,162	66.7	5,503,525	2,747,637	1,373,818

* 2017 Population projection

Across PNG, 52.3% (95% CI 47.2, 57.4) of the population slept under a mosquito net and 51.1% (95% CI 46.0, 56.2) under a LLIN the night before the survey. The small difference between use of any type of net and use of an LLIN reflects that non-LLINs have become uncommon after multiple rounds of free LLIN distribution. In households that owned at least one LLIN, 63.4% (95% CI 58.9, 67.7) of the people used such a net (Table 8 and Table B3, Appendix B). Among the population with access to an LLIN in their household (based on the access indicator), 76.6% of the people slept under a LLIN the previous night (Table 9). Use among those with access was lowest in the Islands (51.2%) and Highlands Regions (58.1%).

The highest LLIN use was recorded in Momase Region (70.2%), followed by Southern (59.5%), Islands (38.5%) and Highlands (26.0%). In the Highlands Region, the difference in LLIN use between villages located at ≥1600 m altitude (24.1%) and lower-lying villages (34.1%) did not reach statistical significance (P = 0.08, data not in table). LLIN use by the general population was below the national average in the Highlands provinces, NCD, New Ireland, East New Britain and Bougainville.

Differences in LLIN use between rural (51.8%) and urban areas (45.7%) were not found to be statistically significant (P > 0.05).

Young children were more likely to use an LLIN than adolescents and adults. Among children <5 years of age, 59.5% (95% CI 54.5, 64.3) slept under a LLIN the previous night (Table 10 and Table B5, Appendix B) increasing to 72.0% (95% CI 67.2, 76.2) in households that owned at least one LLIN. The lowest LLIN usage was recorded in the age group 15-19 years (43.6%).

Female household members were significantly more likely to use a LLIN than their male counterparts (P < 0.05). However, this was not the case in age groups <15 years. Except for the Highlands Region, differences between male and females were most prominent in adolescents and adults (Figure 4). Among pregnant women aged 15-49 years, 59.6% (95% CI 46.9, 71.2) slept under a LLIN the previous night increasing to 70.5% (95% CI 59.2, 79.8) if they lived in a household owning at least one LLIN (Table 11).

Table 8. Use of mosquito nets by persons in the household

Percentage of the de facto household population who slept the night before the survey under a mosquito net (treated or untreated) and under a long-lasting insecticidal net (LLIN); and among the de facto household population in households with at least one LLIN, percentage who slept under a LLIN the night before the survey, according to background characteristics, Papua New Guinea, 2016-2017

	Household population			Household population in households with at least one LLIN	
Background characteristic	Percentage who slept under any mosquito net last night	Percentage who slept under an LLIN last night	Number of persons	Percentage who slept under an LLIN last night	Number of persons
Age					
<5	60.9	59.5	2,094	72.0	1,797
<1	66.6	64.1	310	73.1	274
1-4	59.9	58.7	1,784	71.8	1,523
5-9	55.7	54.1	2,193	65.9	1,877
10-14	50.2	48.8	1,908	59.7	1,620
15-19	44.7	43.6	1,552	54.6	1,279
20+	51.0	50.0	7370	62.9	6,083
	**	**		**	
Sex					
Male	51.0	49.7	7500	62.0	6,341
Female	53.7	52.4	7617	64.7	6,315
	*	*		*	
Residence					
Rural	53.1	51.8	13459	64.5	11,306
Urban	45.8	45.7	1658	54.6	1,350
Region					
Southern	59.7	59.5	4,396	67.3	3,921
Highlands	26.2	26.0	2,378	44.4	1,293
Momase	73.3	70.2	4,538	78.4	3,975
Islands	38.6	38.5	3,805	44.1	3,467
	**	**		**	
Overall	52.3	51.1	15,117	63.4	12,656
(95% CI)	(47.2, 57.4)	(46.0, 56.2)		(58.9, 67.7)	

*Differences between categories are statistically significant at P < 0.05

** Differences between categories are statistically significant at P < 0.001

Table 9. Use of LLIN among those with access

Percentage of the de facto household population who slept the night before the survey under a long-lasting insecticidal net (LLIN) among the de facto household population that has access to a LLIN within their household, Papua New Guinea, 2016-2017

Background characteristic	Percentage of the de facto population with access to an LLIN[1]	Percentage who slept under an LLIN last night	Number of persons	Number of persons with access to an LLIN	Number of persons who slept under an LLIN last night	Percentage who slept under an LLIN among those with access[2]
Region						
Southern	72.0	59.5	4,396	3,165	2,616	82.7
Highlands	44.7	26.0	2,378	1,064	618	58.1
Momase	76.3	70.2	4,538	3,463	3,186	92.0
Islands	75.3	38.5	3,805	2,863	1,465	51.2
Overall	66.7	51.1	15,117	10,083	7,725	76.6

[1] Percentage of de facto household population who could sleep under an LLIN if each LLIN in the household were used by up to two people.
[2] Calculation of indicator according to Kilian A *et al.* Malar J 2013, 12:314 [16].

Table 10. Use of mosquito nets by children <5 years of age

Percentage of children under age 5 who, the night before the survey, slept under a mosquito net (treated or untreated) and under a long-lasting insecticidal net (LLIN); and among children under age 5 in households with at least one LLIN, percentage who slept under a LLIN the night before the survey, according to background characteristics, Papua New Guinea, 2016-2017

	Children under age 5 in all households			Children under age 5 in households with at least one LLIN	
Background characteristic	Percentage who slept under any mosquito net last night	Percentage who slept under an LLIN last night	Number of children	Percentage who slept under an LLIN last night	Number of children
Sex					
Male	60.4	59.2		72.5	
Female	61.4	59.8		71.4	
Residence					
Rural	61.2	59.6	1,900	72.8	1,626
Urban	57.8	57.8	194	64.3	171
Region					
Southern	71.6	71.3	658	77.4	612
Highlands	34.0	34.0	280	55.3	156
Momase	75.6	72.0	675	80.8	590
Islands	52.8 *	52.5 *	481	59.4 *	439
Overall	60.9	59.5	2,094	72	1,797
(95% CI)	(55.8, 65.7)	(54.5, 64.3)		(67.2, 76.2)	

*Differences between categories are statistically significant at P < 0.001

Table 11. Use of mosquito nets by pregnant women

Percentage of pregnant women age 15-49 who, the night before the survey, slept under a mosquito net (treated or untreated) and under a long-lasting insecticidal net (LLIN); and among pregnant women age 15-49 in households with at least one LLIN, percentage who slept under an LLIN the night before the survey, according to background characteristics, Papua New Guinea, 2016-2017

	Among pregnant women age 15-49 in all households			Among pregnant women age 15-49 in households with at least one LLIN	
Background characteristic	Percentage who slept under any mosquito net last night	Percentage who slept under an LLIN last night	Number of pregnant women	Percentage who slept under an LLIN last night	Number of pregnant women
Residence					
Rural	65.4	63.4	124	73.6	112
Urban	9.8	9.8	12	15.3	7
	*	*		*	
Region					
Southern	72.7	67.9	51	78.6	46
Highlands	38.4	38.4	14	56.4	8
Momase	85.3	83.2	37	89.4	33
Islands	41.7	41.7	34	42.7	32
	*	*		*	
Total	61.5	59.6	136	70.5	119
(95% CI)	(48.5, 73.0)	(46.9, 71.2)		(59.2, 79.8)	

*Differences between categories are statistically significant at P < 0.05

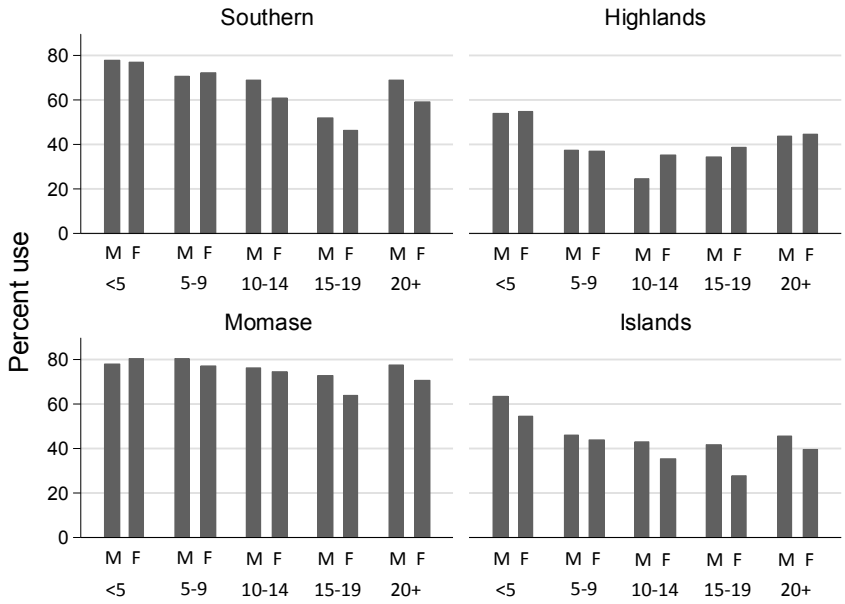


Figure 4. Use of mosquito nets according to sex, age group and region

Target: On a national level, the targets of 70% LLIN access, 60% LLIN use among all age groups, 65% use in children <5 years and pregnant women, and 82% use among those with access were missed in the general population (though for some indicators, the target is within the 95% confidence limit of the survey result). However, in households owning at least one LLIN, all use targets were exceeded. The LLIN use target for all age groups was missed in NCD, Milne Bay, the Highlands and Islands Provinces, while most provinces of Southern and provinces in Momase Region reached the target (Appendix B). The situation was similar for children <5 years; however, in Milne Bay and Manus Provinces, coverage in this age group was above 65%. The pregnant women target was reached on a regional level in Southern and Momase Regions; due to the small sample size, provincial measures were not calculated.

Trend: Overall, access, usage of any net and LLINs in the general population and in children <5 years of age has remained stable since 2011, with small decreases since the last national survey. LLIN use in pregnant women has increased over time (Figure 5).

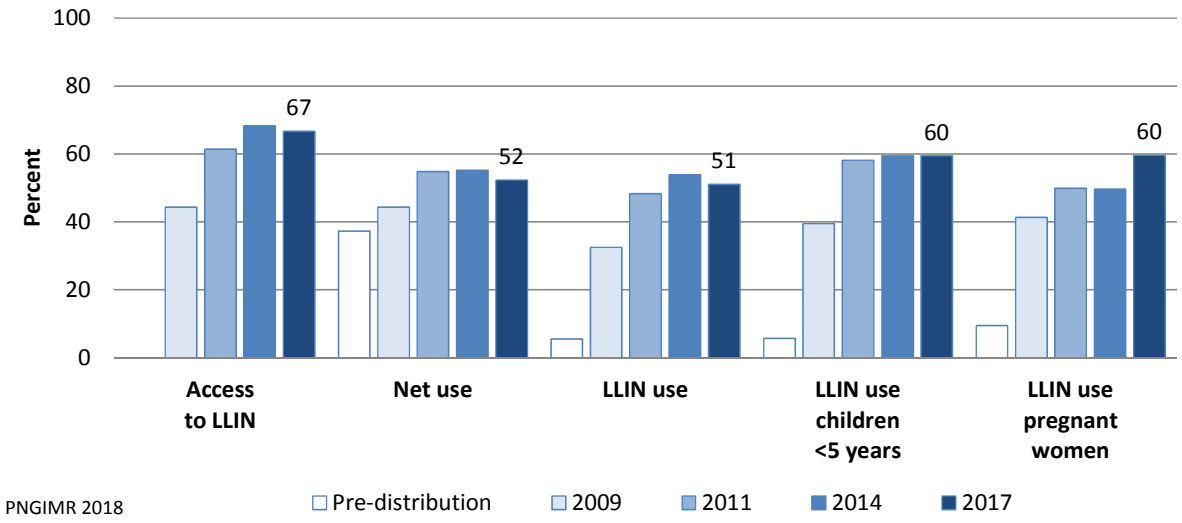


Figure 5. Trends in access to and use of mosquito nets

Pre-distribution estimate and national survey results 2009-2017. Data source: PNGIMR surveys.

3.3 Malaria prevention: exposure to malaria messages

Among all heads of surveyed households, 8.0% (95% CI 6.7, 9.6) reported having received any information on malaria in the past three months. There were significant regional differences; household heads in the Islands Region most frequently reported having received information on malaria (12.2%) (Table 12). The most frequently reported source of information were health workers. It is not possible to establish whether this exposure occurred during a health facility visit or during outreach activities (Figure 6).

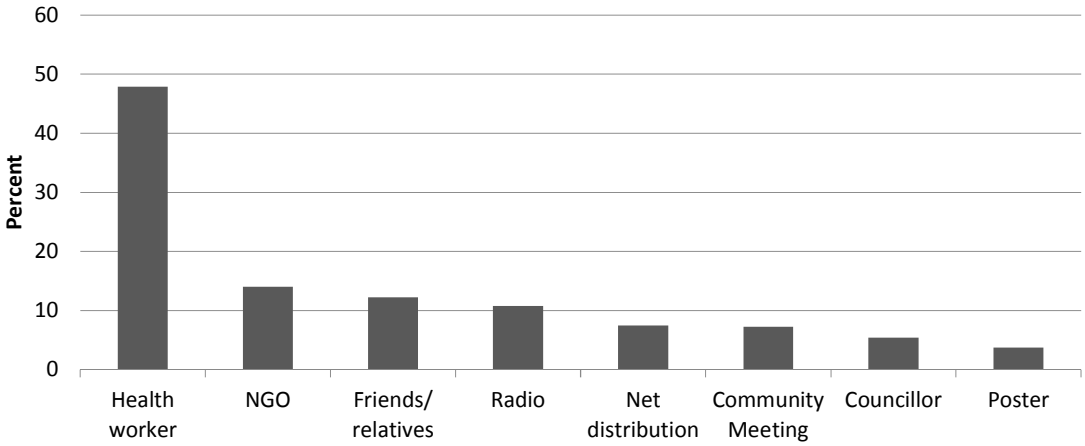


Figure 6. Sources of malaria information among household heads who received information in the past 3 months. More than one answer was allowed.

Table 12. Media exposure to malaria messages

Percentage of household heads who have seen or heard a message about malaria in the past 3 months, Papua New Guinea, 2016-2017

Background characteristic	Information from any source[1]	Number of household heads
Residence		
Rural	8.0	2,493
Urban	8.2	250
Region		
Southern	5.6	752
Highlands	6.1	511
Momase	9.3	739
Islands	12.2 *	741
Total	8.0	2,743
(95% CI)	(6.7, 9.6)	

[1] Weighted proportions

*Difference between categories is statistically significant at P < 0.05

3.4 Prevalence of malaria infection

This chapter presents results of the prevalence of malaria infection in the general population assessed in household members above 6 months of age. Microscopy results are presented overall and by *Plasmodium* species. Microscopy results available for 11,358 individuals should be regarded as the gold standard; village-level mRDT results available only from a sub-set of provinces are presented only for comparative purposes in Appendix C.

The following target was defined in the Global Fund grant performance framework:	
Parasite prevalence: Proportion of children aged 6-59 months with malaria infection (I-5)	**2%**

Below 1600 m altitude, 7.1% (95% CI 5.0, 10.1) of people were infected with malaria parasites, in highland areas at 1600 m and above, only 0.9% (95% CI 0.2, 4.5). On a national level, infections with *P. falciparum* were more common than infections with *P. vivax* (Table 13). Mixed infections were found in 0.4% (95% CI 0.2, 0.6) of people below 1600 m but not in highland areas. *P. malariae* was rare and no infections with *P. ovale* were detected.

In the age group of children <5 years of age living in villages <1600 m altitude, 9.5% (95% CI 6.7, 13.4) were infected with malaria parasites, while no malaria infections were found in the 86 children surveyed in highland villages at 1600 m and above (Table 14).

Malaria prevalence was the highest in Momase (10.6%) and lowest in the Highlands Region (0.7%) (Table 15). No infections were found in villages between 1200 and 1600 m altitude but due to the population distribution in PNG [1], the survey sample at these altitudes was small. Overall, infections were significantly less common in urban than in rural areas.

Madang stood out as the province with the highest prevalence, reaching 16.0%, followed by Milne Bay (10.8%), East Sepik (8.8%), New Ireland (8.7%) and Sandaun (7.9%) (Tables C1 and C2, Appendix C).

Table 13. Prevalence of malaria infection

Percentage of persons above 6 months of age classified by light microscopy as having malaria, in villages <1600 m altitude, ≥1600 m altitude, and overall, Papua New Guinea, 2016-2017

	Malaria prevalence according to microscopy[1]					
Village location	Any species	*P. falciparum*	*P. vivax*	*P. malariae*	Mixed *P.f.* & *P.v.*	Number of persons
<1600 m altitude	7.1	4.8	2.6	0.1	0.4	10,013
95% CI	(5.0, 10.1)	(3.2, 7.2)	(1.8, 3.6)	(0.0, 0.3)	(0.2, 0.6)	
≥1600 m altitude	0.9	0.8	0.001	0.0	0.0	1345
95% CI	(0.2, 4.5)	(0.1, 0.5)	(0.0, 0.6)			
Overall	6.2	4.2	2.2	0.001	0.3	11,358
95% CI	(4.3, 8.8)	(2.8, 6.3)	(1.6, 3.1)	(0.0, 0.2)	(0.2, 0.5)	

[1]Age-standardized and weighted

Table 14. Prevalence of malaria infection in children <5 years of age

Percentage of children between 6 months and 5 years of age classified by light microscopy as having malaria, in villages <1600 m altitude, ≥1600 m altitude, and overall, Papua New Guinea, 2016-2017

	Malaria prevalence according to microscopy[1]					
Village location	Any species	*P. falciparum*	*P. vivax*	*P. malariae*	Mixed *P.f.* & *P.v.*	Number of persons
<1600 m altitude	9.5	5.1	4.5	0.3	0.4	1,444
95% CI	(6.7, 13.4)	(3.5, 7.4)	(2.8, 7.2)	(0.1, 0.9)	(0.2, 0.9)	
≥1600 m altitude	0.0	0.0	0.0	0.0	0.0	86
Overall	8.8	4.7	4.2	0.3	0.4	1,530
95% CI	(6.2, 12.4)	(3.2, 6.9)	(2.6, 6.6)	(0.0, 0.9)	(0.2, 0.9)	

[1]Weighted

Table 15. Prevalence of malaria infection by background characteristics

Percentage of persons above 6 months of age classified by light microscopy as having malaria, according to background characteristics, Papua New Guinea, 2016-2017

Background characteristic	Malaria prevalence according to microscopy[1]					
	Any species	*P. falciparum*	*P. vivax*	*P. malariae*	Mixed *P.f.* & *P.v.*	Number of persons
Altitude (m)						
<1200	7.4	5.0	2.7	0.1	0.4	9,916
1200 to 1599	0.0	0.0	0.0	0.0	0.0	97
1600+	0.9	0.8	0.001	0.0	0.0	1,345
Residence						
Rural	7.0	4.7	2.5	0.1	0.4	10,102
Urban	0.5 **	0.4 **	0.1 **	0.0	0.0	1,256
Region						
Southern	4.2	2.3	2.1	0.1	0.2	3,318
Highlands	0.7	0.7	0.0004	0.0	0.0	1,442
Momase	10.6	7.6	3.4	0.2	0.5	3,929
Islands	2.8	1.6	1.3	0.001	0.001	2,669
Age in years[2]						
<5	8.8	4.7	4.2	0.3	0.4	1,530
<1	2.5	1.4	2.1	0.0	0.9	112
1-4	9.3	5.0	4.3	0.3	0.3	1,418
5-9	12.0	7.3	5.4	0.2	0.9	1,768
10-14	9.0	6.3	3.1	0.1	0.6	1,351
15-19	6.6	4.7	2.2	0.0	0.3	944
20-39	4.4	3.2	1.3	0.0	0.1	3,086
40+	2.9 **	2.4 **	0.6 **	0.1	0.1 *	2,679
Sex						
Female	5.6	3.8	1.8	0.140	0.2	6,009
Male	6.8 *	4.6 *	2.7 *	0.001	0.4	5,349
Women 15-49 years						
Not pregnant	4.1	3.0	1.3	0.0	0.2	3,684
Pregnant	1.8	1.6	0.2	0.0	0.0	138

*Differences between categories are statistically significant at P < 0.05
** Differences between categories are statistically significant at P < 0.001
[1] Age-standardized and weighted
[2] Weighted

Out of the 102 survey villages, no malaria infections were detected in 43 villages and no infections in children <5 years in 65 villages. Villages in which infections were exclusively found in older children or adults may be less likely to have ongoing local transmission. For example, in the Highlands Region, malaria infected individuals were found in only three

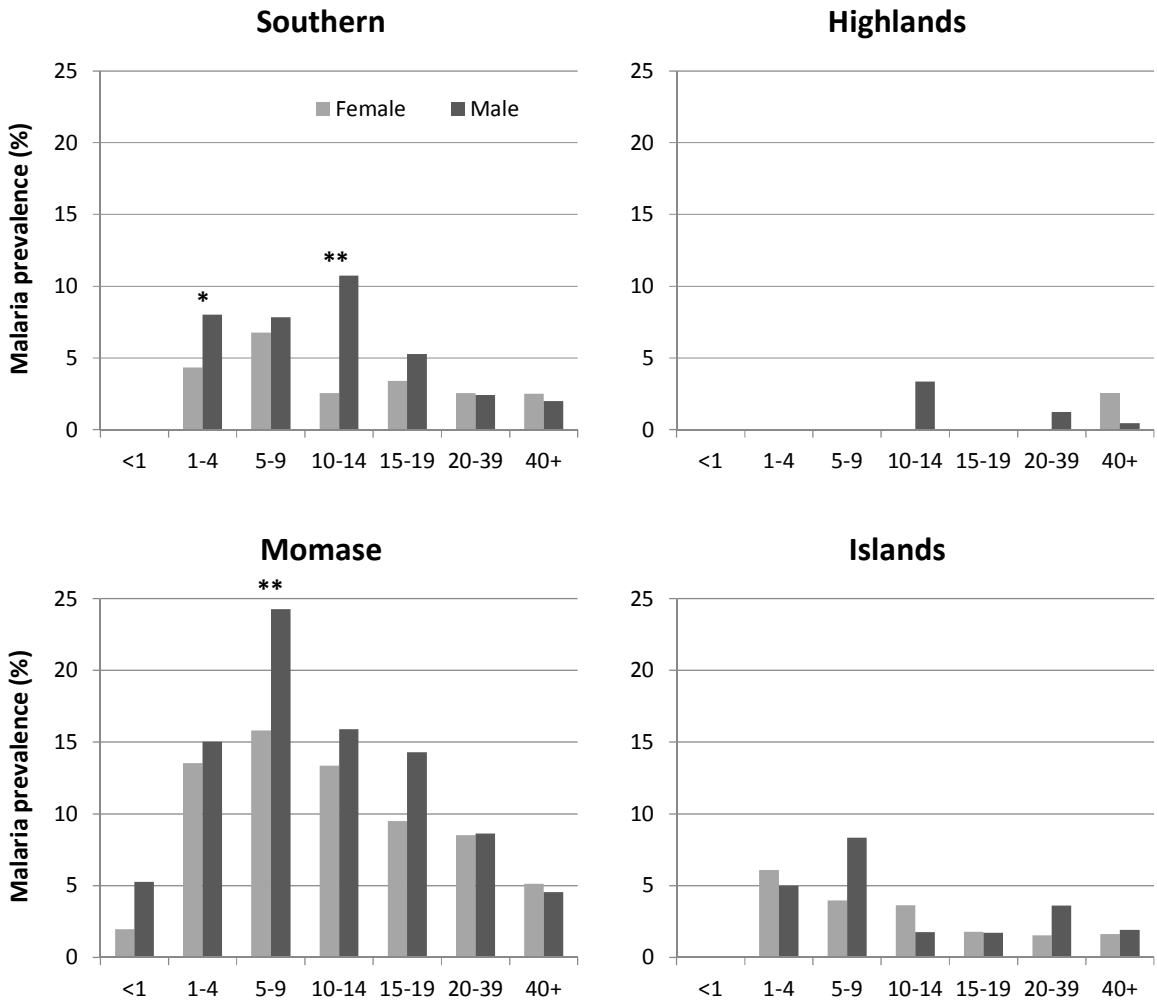
villages, where none of the infections was in children, suggesting imported cases rather than local transmission (Table C3, Appendix C).

On the other end of the spectrum, villages with prevalence values >20% were found in all regions, except in the Highlands. In Madang and East Sepik Provinces, almost all surveyed villages had >10% prevalence in adults and similar values in young children (up to 57.7% in children <5 years in the Madang village of Pereu 2). In the other non-Highlands provinces, there rather appeared to be pockets of high prevalence in children and adults, some villages with infections only in older children and adults, and some villages with no infections at all (Table C3, Appendix C).

Prevalence was higher in males than in females (Table 15), but the difference was only statistically significant in particular age groups in Southern and Momase regions (Figure 7). In children below five years of age living in survey villages <1600 m altitude, there was no statistically significant difference between the overall prevalence in male (10.3%) and female (8.6%) children ($P > 0.05$) (Table C2, Appendix C). In women aged 15-49 years, the difference in prevalence between women reporting to be pregnant and non-pregnant women was not statistically significant (Table 15).

Malaria species composition

P. falciparum was the dominant malaria parasite on both a national- and regional-level (Tables 13-15). However, individual villages with a notably higher prevalence of *P. vivax* than *P. falciparum* were found in the following provinces: Western (1), Milne Bay (1), Oro (1), Madang (2), East Sepik (2), New Ireland (4), East New Britain (2). In almost all of these villages, the *P. vivax* dominance was higher in children <5 years than in the general population (Appendix C).



PNGIMR 2018

Figure 7. Malaria prevalence by age group, sex and region

Statistically significant differences are indicated by * P < 0.05 and ** P < 0.001.

Target: The target of 2% prevalence in children <5 years of age has not been reached on a national or regional level in areas <1600 m altitude where malaria conditions are favourable for transmission. On a provincial level, the target was met in all provinces in the Highlands Region, in 3/6 provinces in Southern Region (Western, Central, NCD), and in 1/4 provinces in the Islands Region (Bougainville) (Table C2, Appendix C).

Trend: Malaria prevalence has dramatically increased across PNG since the last national survey in 2013/14 (Figure 8). The increase is most pronounced in Southern and Momase Regions (Figure 9). On a national level, the prevalence of infection with malaria parasites in the general population was higher in 2016/17 (7.1%) than it was in 2010/11 (5.1%) [8]. This measure does not yet account for infections with low-level parasitaemia, which are common in PNG [13], and all of which need to be treated effectively with a full course of an efficacious drug in order to interrupt malaria transmission.

If we were to extrapolate the general population prevalence from 2013/14 and from 2016/17 into an estimate of the total number of people infected with light microscopy detectable malaria parasites at the respective time periods, then this would indicate an increase in the size of the total population infected with malaria parasites from 50,309 in 2014 to 432,000 in 2017, representing an 8.6-fold increase[7].

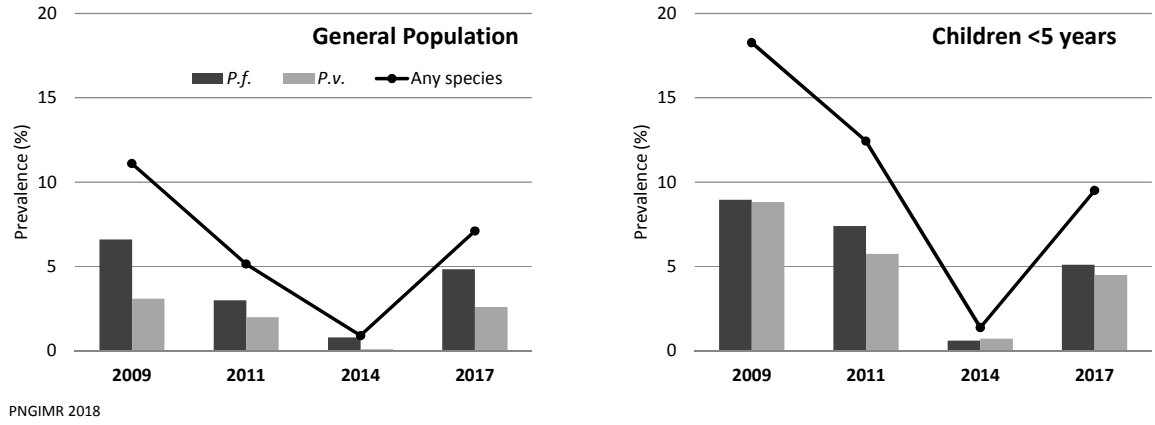


Figure 8: Country-wide malaria parasite prevalence in the general population and in children <5 years of age (< 1600 m altitude)

[7] Based on a population of 7.6 million in 2014, 8.3 million in 2017, and 30% of the population living in areas ≥1600 m altitude (estimated from previous survey samples).

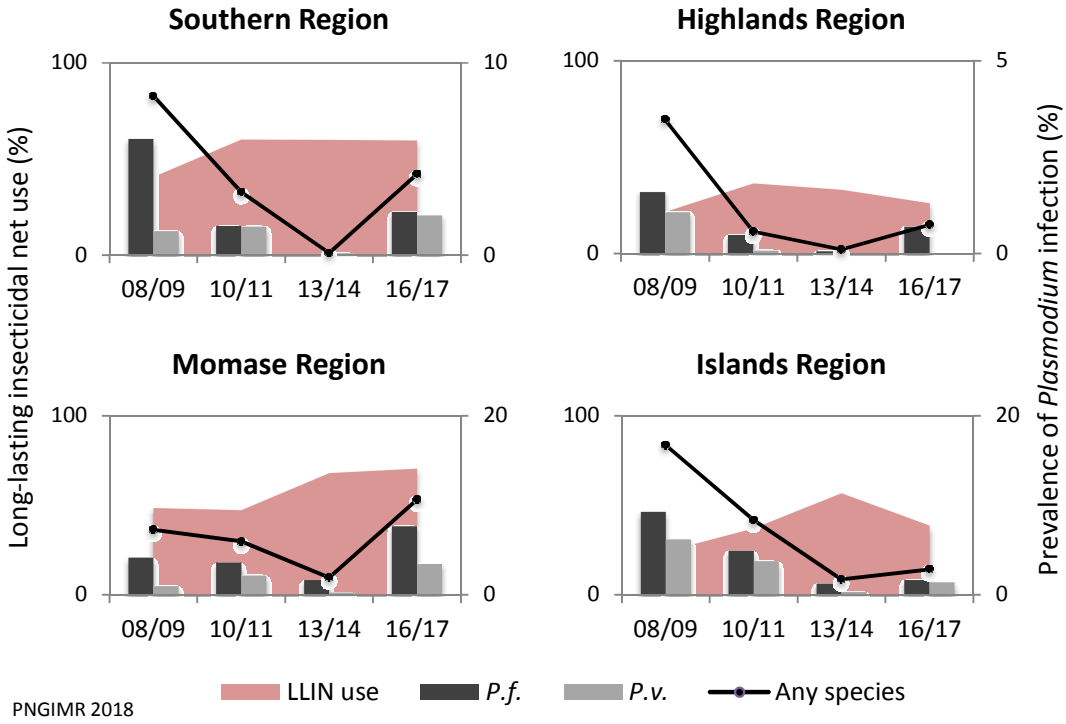


Figure 9: LLIN use and malaria parasite prevalence in the general population by region

Note: right y-axes (prevalence) have different scales.

3.5 Prevalence of malaria-associated morbidity

This chapter present selected indicators of morbidity that are generally associated with malaria, including fever, anaemia, and splenomegaly. Anaemia is multifactorial [22], influenced by factors such as infectious diseases, nutrition, or genetic blood disorders, while splenomegaly has been associated with chronic malaria infection.

A recent fever was reported by 3.6% (95% CI 2.9, 4.4) of all household members and 1.3% (95% CI 1.0, 1.8) had measured axillary temperature >37.5°C on the day of the survey. Reported fever and axillary temperature >37.5°C was most common in children <1 year of age (Table 16). Fever was more common in rural than in urban areas and less common with increasing age.

Anaemia was detected in 62.5% (95% CI 58.6, 66.4) of all household members and 3.5% (95% CI 2.8, 4.4) had severe anaemia. Anaemia was less common in the Highlands regions than in the lowlands and anaemia prevalence decreased with age.

Of all children 2-9 years of age, 1.5% (95% CI 0.8, 2.9) had an enlarged spleen (splenomegaly). Splenomegaly was most frequently detected in the provinces of Sandaun (17.8%), New Ireland (3.8%), Madang (2.5%) and Gulf (2.5%) (Table D1, Appendix D).

Table 16. Fever, anaemia, severe anaemia, and splenomegaly

Percentage of persons with reported fever, acute fever, haemoglobin below the WHO threshold for anaemia and severe anaemia, and splenomegaly, according to background characteristics, Papua New Guinea, 2016-2017

Background characteristic	Reported fever	Number of persons	Acute fever[1]	Number of persons	Anaemia[2]	Severe anaemia[2]	Number of persons	Splenomegaly[3]	Number of children
Altitude (m)									
<1200	3.8	9,899	1.4	9,540	73.1	4.6	9,898	2.4	2,623
1200 to 1599	0.0	97	1.3	97	35.7	1.3	97	0.0	18
1600+	3.5	1,383	0.2	1,228	26.3	0.1	1,383	0.4	214
Residence									
Rural	4.1	10,123	1.4	9,683	66.1	3.9	10,122	2.4	2,583
Urban	0.8	1,256	0.3	1,182	69.5	4.5	1,256	0.0	272
Region									
Southern	3.0	3,369	0.9	3,338	73.2	4.1	3,368	0.7	954
Highlands	3.4	1,480	0.3	1,325	26.8	0.2	1,480	0.4	232
Momase	4.5	3,862	1.8	3,775	78.3	6.1	3,862	4.7	1,037
Islands	3.7	2,668	1.2	2,427	65.3	2.8	2,668	0.9	632
Age in years									
<5	6.0	1,520	2.5	1,457	80.5	8.1	1,520		
<1	7.4	108	2.8	108	96.3	13.9	108		
1-4	5.9	1,412	2.5	1,349	79.2	7.6	1,412	1.9	1,138
5-9	4.0	1,760	1.9	1,697	77.7	5.3	1,760	2.5	1,717
10-14	3.9	1,348	2.7	1,276	70.6	2.4	1,348		
15-19	2.5	946	1.1	903	61.2	2.5	946		
20-39	2.9	3,103	0.6	2,950	58.7	3.4	3,102		
40+	3.7 **	2,702	0.4 **	2,582	62.8 **	3.1 **	2,702		
Sex									
Female	3.5	6,020	1.2	5,742	71.0	4.6	6,020	1.9	1,356
Male	4.1	5,359	1.4	5,123	62.9 **	3.5 *	5,358	2.5	1,499
Total	3.6	11,379	1.3	10,865	62.5	3.5	11,378	1.5	2,855
(95% CI)	(2.9, 4.4)		(1.0, 1.8)		(58.6, 66.4)	(2.8, 4.4)		(0.8, 2.9)	

[1] Acute fever was defined as axillary temperature >37.5°C

[2] Anaemia and severe anaemia were defined according to WHO recommendations, which include age-specific cut-offs and altitude corrections (WHO 2011).

[3] Splenomegaly was defined as a palpable spleen (i.e. Hackett grade 1 to 5) in children aged 2-9 years.

3.6 Treatment-seeking for fever

This section presents details on the treatment-seeking behavior of the 272 household members reporting an episode of fever in the two weeks preceding the survey. Sixteen (5.9%) of these cases reported at least one symptom of severe disease (incl. difficulty breathing, convulsions, or loss of consciousness).

The following target was defined in the Global Fund grant performance framework:

Proportion of children under five years old with fever in the last two weeks for whom advice or treatment was sought	**65%**

For 42.9% (95% CI 32.5, 54.1) of the fever cases in the general population and for 45.3% (95% CI 29.8, 61.7) of fever cases in children <5 years of age, advice or treatment was sought outside the person's home (Table 17). Due to the small number of cases, most comparisons between categories did not reach statistical significance. A diagnostic test from a finger or heel prick was done in 22.6% (95% CI 16.0, 30.9) of the cases in the general population and in 24.8% (95% CI 16.0, 36.4) of the cases in children <5 years.

Table 17. Diagnosis and treatment of persons with fever

Percentage of persons and children under age 5 with fever in the 2 weeks preceding the survey for whom advice or treatment was sought, outside the home, and percentage who had blood taken from a finger or heel for testing, according to background characteristics, Papua New Guinea, 2016-2017.

	Persons with fever[1]			Children under age 5 with fever[1]		
Background characteristic	Percentage for whom advice or treatment was sought[2]	Percentage who had blood taken from a finger or heel for testing	Number of persons	Percentage for whom advice or treatment was sought[2]	Percentage who had blood taken from a finger or heel for testing	Number of children
Residence						
Rural	42.0	21.4	245	42.1	22.1	67
Urban	52.8	35.3	27	84.4	58.3	6
Region						
Southern	58.1	29.0	97	55.1	25.0	28
Highlands	24.6	5.0	15	13.2	0.0	3
Momase	36.8	21.6	120	38.6	25.4	31
Islands	60.9	34.2	40	63.9	33.6	11
Sex						
Female	36.7	21.3	133	45.0	18.1	34
Male	49.0	24.0	139	45.5	30.8	39
Total	42.9	22.6	272	45.3	24.8	73
(95% CI)	(32.5, 54.1)	(16.0, 30.9)		(29.8, 61.7)	(16.0, 36.4)	

[1] Weighted
[2] Includes advice or treatment from sources outside the home.

Most people sought care in health facilities (40.6% in the general population and 44.5% in children <5 years). Aid posts were the most frequently visited facility for the general population but children <5 years were most commonly brought to health centres (23.0%). Other treatment sources were uncommon (Table 18).

Table 18. Source of advice or treatment for children with fever

Percentage of persons and children under age 5 with fever in the 2 weeks preceding the survey for whom advice or treatment was sought from specific sources, Papua New Guinea, 2016-2017

	Percentage for whom advice or treatment was sought from each source[1]:			
	Persons with fever		Children under age 5 with fever	
Source	Among persons with fever	Among persons with fever for whom advice or treatment was sought[2]	Among children with fever	Among children with fever for whom advice or treatment was sought[2]
Public sector				
Health facility	40.6	94.6	44.5	98.4
- Hospital	2.0	4.8	4.9	10.7
- Health Centre	16.9	39.4	23.0	50.9
- Aid Post	21.8	50.7	19.0	42.0
- Village Health Volunteer	0.5	1.0	0.0	0.0
Private medical sector				
Pharmacy	5.7	13.4	0.0	0.0
Other private sector				
Shop	0.0	0.0	0.0	0.0
Other	0.0	0.0	0.0	0.0
Number	272	115	73	33

[1] Weighted
[2] Includes advice or treatment from sources outside the home.

The most commonly used drugs were antipyretics (29.6%) and antibiotics (20.2%) (Table 19). An antimalarial medicine was taken by 16.5% (95% CI 10.5, 25.0) of the fever cases and by 13.4% (95% CI 6.0, 27.5) of cases in children <5 years. The most frequently used antimalarial was the first-line drug artemether-lumefantrine (13.9%), followed by artemether or artesunate injections (13.3%) and primaquine (12.7%). Use of artemisinin monotherapies was uncommon; 32 of the 35 cases (91.4%) that used artemether tablets or artemether/artesunate injections as monotherapy also reported taking artemether-lumefanrine.

A total of 34 cases (53.1% of those reporting a test was done) reported having received a positive malaria test result and 46 cases (40% of those fever for whom advice or treatment was sought outside home) reported being told by a health worker that they had malaria. An

antimalarial was taken by 89.7% of cases with a reported positive test and by 82.8% who had been told they had malaria. The first-line treatment artemether-lumefantrine was used by 85.3% of reportedly test-positive persons, and by 89.6% of test-positive children <5 years. Figure 9 illustrates that only a very small proportion of all potential malaria cases were tested and treated. Antibiotics were taken primarily by those cases that did not test positive for malaria or were not told they had malaria (Table 19).

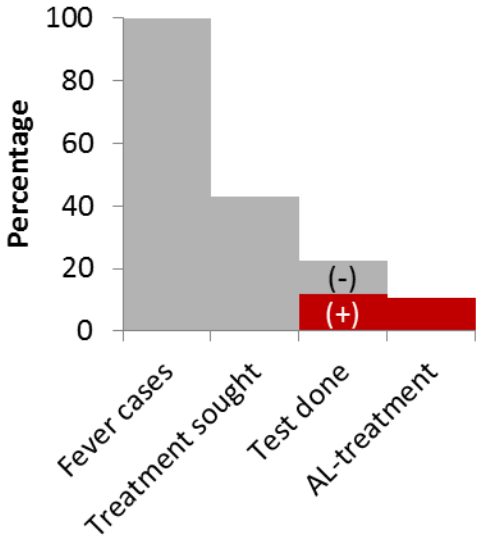


Figure 9. Percentage of fever cases for whom treatment was sought outside home, and who were tested and treated with artemether-lumefantrine (AL) in case of a positive test.

Reason for not attending a health facility

Of all the fever cases who did not seek advice or treatment from a health facility, 118 provided a reason. The most frequently cited reasons are displayed in Figure 10. A long distance to the nearest health facility was the most frequently cited reason, often in combination with a lack of money for transport or medication, and a lack of medicines or poor quality at the facility. Or in the words of survey respondents:

> *"Because the health facility is too far, it will take six hours to paddle by canoe and then walk."*
>
> Respondent from Kotaure village, Oro Province

> *"Because the Aid Post was run down with no medical drugs, road access was really bad, distance to town nearly two hours ride and finally PMV [bus] fares. All these cause me not to seek treatment in any elsewhere."*
>
> Respondent from Duaug village, Madang Province

Many respondents also mentioned that the illness was not serious, that it got better, or they would wait for it to get more serious before attending a health facility. This was often mentioned in combination with relying on home treatment. Or, as one respondent explained:

> *"Because I believe that treating my son with what I have will heel him. And the other reason the health facility is some hours walk."*
> Respondent from Silaling village, Madang Province.

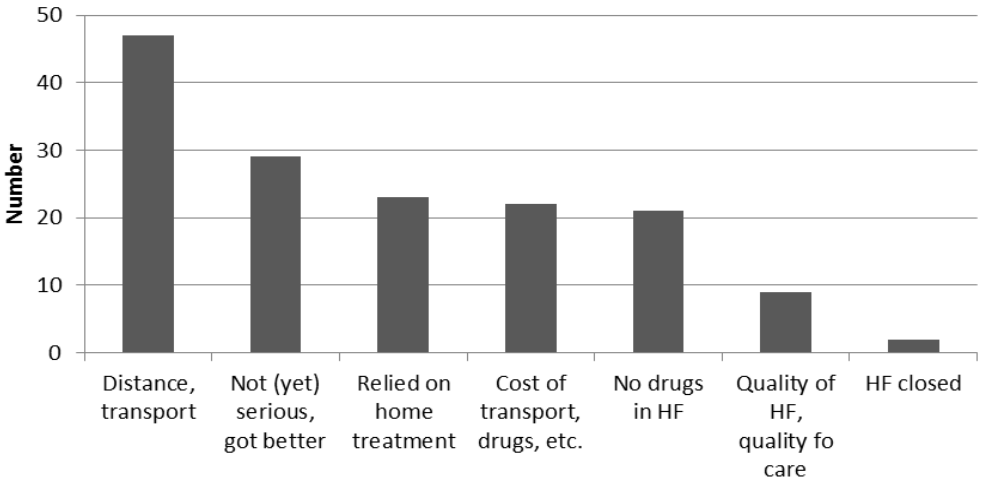
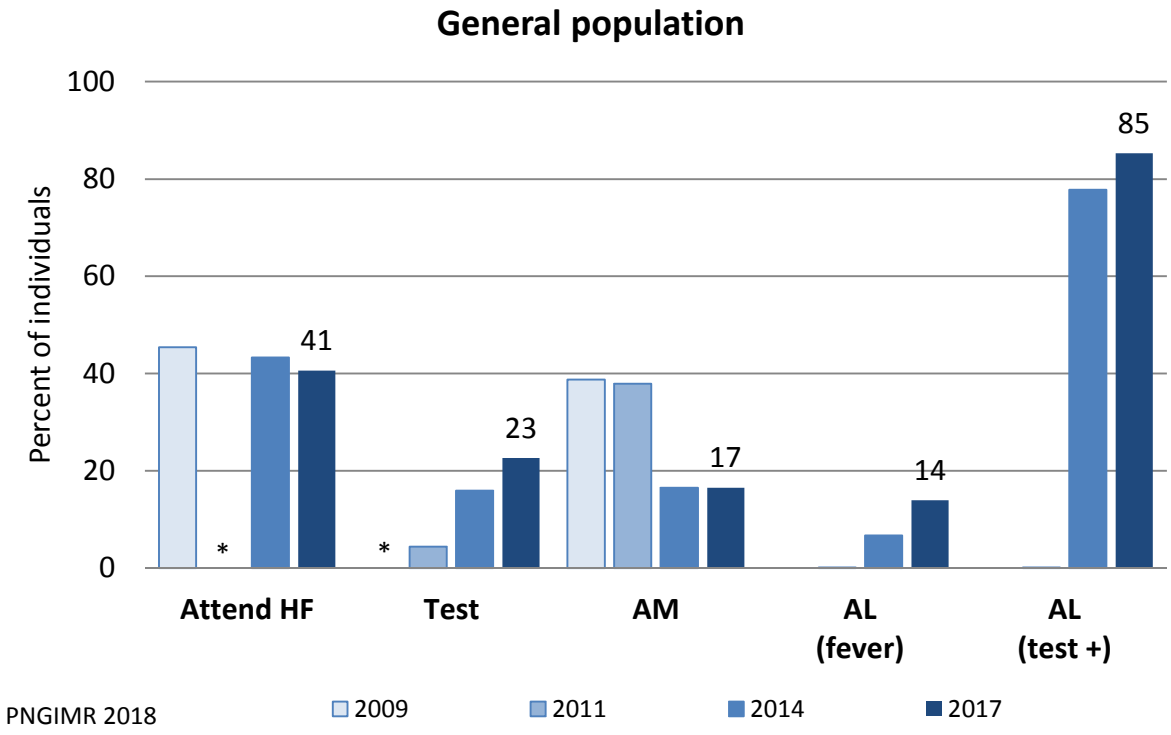


Figure 11. Frequency of reported reasons for not attending a health facility among all 118 persons reporting a reason.

Target: The target of 65% of children with a fever in the past two days seeking advice or treatment has not been reached on a national or regional level. Sub-national numbers are difficult to interpret due to the small sample size (Table E1, Appendix E).

Trend: The percentage of fever cases brought to a health facility for treatment has remained almost constant and below 50% since 2009 (Figure 11). While the testing rate has steadily increased, still only about half of all cases that attend a health facility are tested. The proportion of test-positive cases receiving the first-line treatment has further increased, yet remains below 100%.



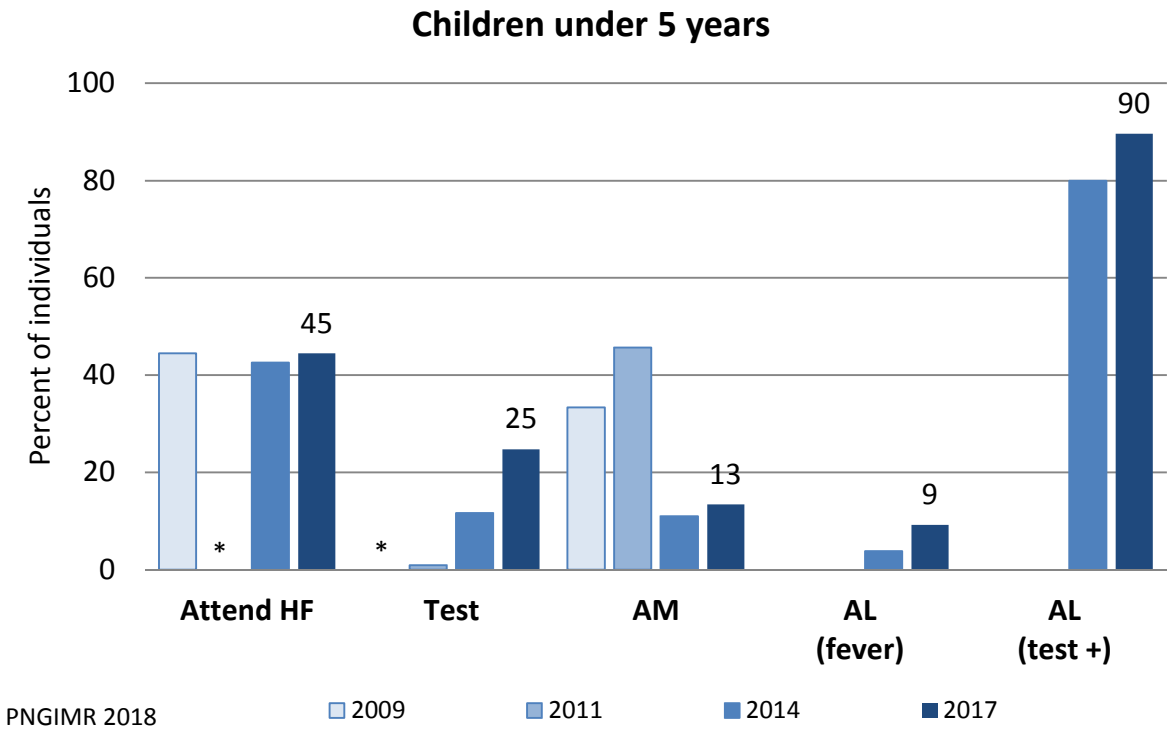


Figure 11. Trends in treatment seeking indicators in the general population and in children <5 years of age. * indicates no data available. National survey results 2009-2017. Source: PNGIMR surveys.

Table 19. Type of drugs used

Among persons with fever in the 2 weeks preceding the survey, percentage who took specific drugs, according to background characteristics, Papua New Guinea, 2016-2017

	Percentage of persons who took[1]:										
Background characteristic	Any antimalarial	AL	Primaquine	SP/ Fansidar	Chloroquine	Amodiaquine	Artemether tablets	Artesunate or artemether injection/IV	Antibiotic	Anitpyretic	Number of persons with fever
Residence											
Rural	15.9	13.0	11.7	1.2	0.2	0.4	0.6	12.3	19.8	27.6	255
Urban	23.0	23.0	23.0	0.0	0.0	0.0	0.0	23.0	23.6	49.9	27
Region											
Southern	16.4	15.2	14.0	0.0	0.8	0.0	0.0	10.4	26.8	38.1	97
Highlands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.2	31.7	15
Momase	19.3	14.9	13.9	2.0	0.0	0.7	1.0	16.7	15.1	20.9	120
Islands	23.5	23.5	19.2	0.0	0.0	0.0	0.0	19.2	21.9	56.4	40
Age in years											
<5	13.4	9.2	9.2	2.1	0.0	0.0	0.0	11.3	28.2	32.6	73
5+	17.5	15.5	13.9	0.7	0.3	0.5	0.7	13.9	17.5	28.7	209
Sex											
Female	18.6	15.1	13.0	2.1	0.5	0.0	1.1	14.5	16.8	26.4	133
Male	14.5	12.8	12.4	0.0	0.0	0.7	0.0	12.1	23.5	32.8	139
Test result											
No malaria	5.3	3.0	1.6	0.6	0.3	0.4	0.0	2.4	23.0	30.6	248
Malaria	89.7 **	85.3 **	85.3 **	4.0	0.0	0.0	4.0 *	84.3 **	1.8 *	23.4	34
Clinician diagnosis											
No malaria	2.0	1.8	0.3	0.0	0.3	0.0	0.0	0.0	23.2	31.2	236
Malaria	82.8 **	69.6 **	69.6 **	5.9 *	0.0	1.9	3.0 *	73.9 **	6.4 *	22.5	46
Total	16.5	13.9	12.7	1.1	0.2	0.4	0.5	13.3	20.2	29.6	272
95% CI	(10.5, 25.0)	(7.7, 23.9)	(7.2, 21.5)	(0.3, 3.9)	(0.0, 1.8)	(0.0, 2.9)	(0.0, 4.01)	(7.8, 21.6)	(13.3, 29.4)	(22.1, 38.5)	

[1] Weighted
AL = Artemether-lumefantrine, SP = Sulphadoxine-pyrimethamine

4 DISCUSSION AND RECOMMENDATIONS

Malaria prevalence

With major budget support from the Global Fund, PNG made significant progress in malaria control between 2004 and 2014 leading to an unprecedented decline in malaria. Prevalence of malaria infection below 1600 m altitude decreased from 11% in 2008/09 to <1% in 2013/14 [8]. This reduction was a historical success, particularly considering the complexity of the malaria epidemiology and operational challenges in the PNG setting.

Yet, since 2013/14, there has been a dramatic resurgence in malaria across PNG resulting in levels of prevalence higher than in 2010/11. Within three years, the estimated number of people across PNG infected with malaria parasites increased 8.6-fold to 432,000 in 2017. In particular, the provinces of Momase Region (most notably Madang, East Sepik and Sandaun), the large islands of New Britain and New Ireland, and Milne Bay and Oro in Southern Region have experienced a substantial increase in malaria prevalence at the general population level.

This resurgence in malaria coincided with: (1) a reduction in the Global Fund support to the PNG malaria control programme after 2013 [23]; (2) a simultaneous decline in PNG public expenditure in the health sector [24]; and (3) a decrease in the availability of artemisinin-based combination treatment and RDTs across PNG [25], including extended stock-outs in many places. At the same time, entomological studies conducted by the PNGIMR have confirmed frequent outdoor biting of local *Anopheles* species and a shift in peak biting to earlier times in the evening [26]. Both behavioural features may contribute to reducing the effectiveness of LLIN. Insecticide resistance, the other major threat to the effectiveness of LLINs, has not yet been detected in PNG [27, 28].

Lessons from the past clearly show that relaxation of control leads to malaria resurgences in environments that are favourable for malaria transmission, such as most parts of PNG [29, 30]. The findings in this report suggest that the country has already entered a phase of resurgence following a decrease in the intensity of malaria control efforts. This report should therefore serve as a wake-up call. Unless the PNG national malaria control programme is adequately supported to re-intensify its malaria control efforts, malaria may continue to increase further, in the same way that occurred after the end of the global eradication programme in the 1980s [30].

Mosquito net coverage

Since the last survey in 2013/14, coverage with mosquito nets, particularly LLINs, has remained stable across PNG. While the proportion of households with one net per two people has further increased, access and use have remained largely unchanged, indicating that household "saturation" with LLINs has not yet been achieved.

LLIN use is determined by a number of factors, including availability of sufficient LLINs in the household or people's perception of the benefit of using a net. In areas, in which ownership and access are low, low use is more likely to be a direct consequence of insufficient availability of nets. In the Highlands provinces, LLIN ownership (60.5%) and access (44.7%) were lowest and lower use than in other areas was therefore expected. On the other hand, as mosquitoes and malaria are less common in the Highlands, then lower use may also be due to a lower perceived benefit of LLIN use.

The difference between LLIN access (the proportion of people who could theoretically use a net) and actual LLIN use is a useful indicator of the approximate coverage gap which is not a result of insufficient availability but rather due to people choosing not to use an available net. This gap was most notable in the Islands Region (75.3% access, 38.5% use), where use was lower in this survey than in 2013-14 (53.9%) [31]. In general, adolescent and adult men were less likely to use an LLIN than other household members. In a previous study conducted in PNG, indifference to disease was found to be the main reason underlying low use among individuals who had access to an LLIN [32].

The survey findings suggest alternative methods of behaviour change communication may be necessary to emphasise the dangers of malaria and encourage the use of existing LLIN. Only 8% of the interviewed household heads reported having received information on malaria in the past 3 months and most of the information people received originated from health workers. While there may be shortfalls in this particular indicator due to the focus on household heads, it certainly reflects a low coverage with malaria-related behaviour change messages. While in the Islands region this proportion was slightly higher at 12.2%, it did not seem to be sufficient to increase LLIN use in the population. Reaching people with behaviour change messages should take into consideration the availability of different means of communication in the population (see chapter 3.1.3).

Malaria treatment

Prompt and effective treatment of clinical malaria cases is essential to prevent progression from uncomplicated to severe disease. Effective treatment of infections is also important to eliminate the parasite reservoir in humans and reduce malaria transmission.

The proportion of fever cases brought for treatment at a health facility remains low (40.6%) across PNG. Other treatment sources remain even less common, reflecting the general absence of a private healthcare or drug retail sector outside of major towns. The perceived lack of severity of a febrile illness, long distance and difficult access to health facilities and the poor quality of services provided including a lack of drugs and other supplies have emerged as main reasons preventing people from accessing a health facility.

Together, low health facility attendance and low testing rates lead to about three quarters of all potential malaria cases in the community missing the opportunity of a proper diagnosis and treatment. If we were to extrapolate the malaria test positivity of approximately 50% reported in this survey to the entire population with a recent fever, then one would expect about 50% of all fevers to be due to malaria, while only 13.9% of all fever cases received the first-line treatment artemether-lumefantrine. As a consequence, 72% of the malarial fevers in the community would not be treated with the recommended first-line antimalarial medicine.

Conclusions

The historical achievement of the PNG national malaria control program, i.e. the reduction of malaria prevalence to <1% by 2013/14, has suffered a major setback in the last three years. As a consequence, the first part of the PNG Department of Health's vision as articulated in the National Malaria Strategic Plan, i.e. 'a substantial and sustained reduction in the burden of malaria in the near term (2014-2018) and mid-term (2019-2024)' has clearly not been achieved [33].

The longer-term goal of malaria elimination by 2030 is less likely now than it was at the time the National Malaria Strategic Plan (2014-2018) was drafted. As the situation presents itself now, the current resurgence in malaria is likely to worsen, causing major suffering for the people of PNG, unless malaria control is re-intensified without delay, inclusive of sufficient funding for vector control, diagnosis, treatment, behaviour change campaigns and operational research.

An immediate concerted effort is therefore required from all stakeholders to ensure that malaria control efforts are brought back on track and intensified, so that the aim of regional malaria elimination by 2030, committed to by political leaders of the Asia Pacific Region, does not become an unreachable goal.

5 REFERENCES

1. Müller I, Bockarie M, Alpers M, Smith T: **The epidemiology of malaria in Papua New Guinea.** *Trends Parasitol* 2003, **19:**253-259.
2. Betuela I, Maraga S, Hetzel MW, Tandrapah T, Sie A, Yala S, Kundi J, Siba P, Reeder JC, Mueller I: **Epidemiology of malaria in the Papua New Guinean highlands.** *Trop Med Int Health* 2012, **17:**1181-1191.
3. Cooper RD, Waterson DGE, Frances SP, Beebe NW, Pluess B, Sweeney AW: **Malaria vectors of Papua New Guinea.** *Int J Parasitol* 2009, **39:**1495-1501.
4. Hetzel MW, Choudhury AAK, Pulford J, Ura Y, Whittaker M, Siba PM, Mueller I: **Progress in mosquito net coverage in Papua New Guinea** *Malar J* 2014, **13:**242.
5. Pulford J, Kurumop SF, Ura Y, Siba PM, Mueller I, Hetzel MW: **Malaria case management in Papua New Guinea following the introduction of a revised treatment protocol.** *Malar J* 2013, **12:**433.
6. Asia Pacific Leaders Malaria Alliance: *Asia Pacific Leaders Malaria Alliance Malaria Elimination Roadmap.* Mandaluyong City, Philippines: Asia Pacific Leaders Malaria Alliance; 2015.
7. Hetzel MW, Pulford J, Maraga S, Barnadas C, Reimer LJ, Tavul L, Jamea-Maiasa S, Tandrapah T, Maalsen A, Makita L, et al: **Evaluation of the Global Fund-supported National Malaria Control Program in Papua New Guinea, 2009-2014.** *P N G Med J* 2014, **57:**7-29.
8. Hetzel MW, Pulford J, Ura Y, Jamea-Maiasa S, Tandrapah A, Tarongka N, Lorry L, Robinson LJ, Lilley K, Makita L, et al: **Insecticide-treated nets and malaria prevalence, Papua New Guinea, 2008-2014.** *Bull World Health Organ* 2017, **95:**695-705B.
9. Hetzel MW, Reimer LJ, Gideon G, Koimbu G, Barnadas C, Makita L, Siba PM, Mueller I: **Changes in malaria burden and transmission in sentinel sites after the roll-out of long-lasting insecticidal nets in Papua New Guinea.** *Parasites & Vectors* 2016, **9:**1-12.
10. Park J-W, Cheong H-K, Honda Y, Ha M, Kim H, Kolam J, Inape K, Mueller I: **Time trend of malaria in relation to climate variability in Papua New Guinea.** *Environ Health Toxicol* 2016, **31:**e2016003-2016000.
11. **Malaria Indicator Survey (MIS) Toolkit** [http://malariasurveys.org/toolkit.cfm]
12. Papua New Guinea Department of Health: *National Malaria Treatment Policy.* Port Moresby: Papua New Guinea Department of Health; 2009.
13. Robinson LJ, Wampfler R, Betuela I, Karl S, White MT, Li Wai Suen CS, Hofmann NE, Kinboro B, Waltmann A, Brewster J, et al: **Strategies for Understanding and Reducing the Plasmodium vivax and Plasmodium ovale Hypnozoite Reservoir in Papua New Guinean Children: A Randomised Placebo-Controlled Trial and Mathematical Model.** *PLoS Med* 2015, **12:**e1001891.
14. Hetzel MW, Morris H, Tarongka N, Barnadas C, Pulford J, Makita L, Siba PM, Mueller I: **Prevalence of malaria across Papua New Guinea after initial roll-out of insecticide-treated mosquito nets.** *Trop Med Int Health* 2015, **20:**1745–1755.

15. MEASURE Evaluation, MEASURE DHS, President's Malaria Initiative, Roll Back Malaria Partnership, UNICEF, World Health Organization: *Household Survey Indicators for Malaria Control.*2013.
16. Kilian A, Koenker H, Baba E, Onyefunafoa EO, Selby RA, Lokko K, Lynch M: **Universal coverage with insecticide-treated nets -- applying the revised indicators for ownership and use to the Nigeria 2010 malaria indicator survey data.** *Malar J* 2013, **12:**314.
17. Sankoh O, Sharrow D, Herbst K, Whiteson Kabudula C, Alam N, Kant S, Ravn H, Bhuiya A, Thi Vui L, Darikwa T, et al: **The INDEPTH standard population for low- and middle-income countries, 2013.** *Glob Health Action* 2014, **7:**23286.
18. World Health Organization: **Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity.** In *Vitamin and Mineral Nutrition Information System*. pp. 6. Geneva2011:6.
19. World Health Organization: *Preventing diarrhoea through better water, sanitation and hygiene: exposures and impacts in low-and middle-income countries.* Geneva: World Health Organization; 2014.
20. World Health Organization, UNICEF: *Progress on sanitation and drinking water: Joint monitoring programme 2015 update and MDG assessment.* New York: World Health Organization, UNICEF; 2015.
21. United Nations General Assembly: **Transforming our world: the 2030 Agenda for Sustainable Development (A/RES/70/1).** pp. 35. New York: United Nations; 2015:35.
22. Manning L, Laman M, Rosanas-Urgell A, Michon P, Aipit S, Bona C, Siba P, Mueller I, Davis TM: **Severe anemia in Papua New Guinean children from a malaria-endemic area: a case-control etiologic study.** *PLoS Negl Trop Dis* 2012, **6:**e1972.
23. **Papua New Guinea: Global Fund Grants** [https://www.theglobalfund.org/en/portfolio/country/list/?loc=PNG&k=a15ecee9-30df-48e8-9bd1-a8ea04e779c6]
24. **Devpolicy PNG Budget Database** [https://devpolicy.crawford.anu.edu.au/png-project/png-budget-database]
25. Kurumop SF, Tandrapah A, Hetzel MW, Siba PM, Mueller I, Pulford J: *The Papua New Guinea National Malaria Control Program: Health facility Surveys, 2010-2106.* Goroka: Papua New Guinea Institute of Medical Research; 2016.
26. Thomsen EK, Koimbu G, Pulford J, Jamea-Maiasa S, Ura Y, Keven JB, Siba PM, Mueller I, Hetzel MW, Reimer LJ: **Mosquito Behavior Change After Distribution of Bednets Results in Decreased Protection Against Malaria Exposure.** *J Infect Dis* 2017, **215:**790-797.
27. Keven JB, Henry-Halldin CN, Thomsen EK, Mueller I, Siba PM, Zimmerman PA, Reimer LJ: **Pyrethroid susceptibility in natural populations of the Anopheles punctulatus group (Diptera: Culicidae) in Papua New Guinea.** *Am J Trop Med Hyg* 2010, **83:**1259-1261.
28. Koimbu G, Czeher C, Katusele M, Sakur M, Kilepak L, Tandrapah A, Hetzel MW, Pulford J, Robinson L, Karl S: **Status of Insecticide Resistance in Papua New Guinea: An Update from Nation-Wide Monitoring of Anopheles Mosquitoes.** *Am J Trop Med Hyg* 2017.
29. Cohen JM, Smith DL, Cotter C, Ward A, Yamey G, Sabot OJ, Moonen B: **Malaria resurgence: a systematic review and assessment of its causes.** *Malar J* 2012, **11:**122.

30. Mueller I, Tulloch J, Marfurt J, Hide R, Reeder JC: **Malaria control in Papua New Guinea results in complex epidemiological changes.** *P N G Med J* 2005, **48:**151-157.
31. Hetzel MW, Pulford J, Gouda H, Hodge A, Siba PM, Mueller I: **The Papua New Guinea National Malaria Control Program: Primary Outcome and Impact Indicators, 2009-2014.** Goroka: Papua New Guinea Institute of Medical Research; 2014.
32. Pulford J, Oakiva T, Angwin A, Bryant M, Mueller I, Hetzel MW: **Indifferent to disease: A qualitative investigation of the reasons why some Papua New Guineans who own mosquito nets choose not to use them.** *Soc Sci Med* 2012, **75:**2283-2290.
33. Papua New Guinea Department of Health: *National Malaria Strategic Plan 2014-2018.* Port Moresby: Department of Health; 2014.
34. Moody A: **Rapid diagnostic tests for malaria parasites.** *Clin Microbiol Rev* 2002, **15:**66-78.

APPENDIX A: SURVEY POPULATION

Table A1. Survey sample

Number of households interviewed by location, and *de facto* household population according to location, age and sex, Papua New Guinea, 2016-2017

Characteristic	Households			*De facto* population		
	Rural	Urban	Total	Rural	Urban	Total
Province						
01 Western	146	0	146	783	0	783
02 Gulf	126	0	126	660	0	660
03 Central	109	0	109	700	0	700
04 NCD	0	120	120	0	940	940
05 Milne Bay	115	0	115	553	0	553
06 Oro	106	30	136	598	162	760
07 Southern Highl. & Hela	n/a	n/a	0	n/a	n/a	0
08 Enga	126	0	126	575	0	575
09 Western Highl. & Jiwaka	137	0	137	696	0	696
10 Chimbu	145	0	145	680	0	680
11 Eastern Highlands	103	0	103	427	0	427
12 Morobe	134	30	164	784	207	991
13 Madang	209	0	209	1575	0	1,575
14 East Sepik	200	0	200	1,159	0	1,159
15 Sandaun	136	30	166	6,81	132	813
16 Manus	178	0	178	825	0	825
17 New Ireland	173	0	173	832	0	832
18 East New Britain	147	40	187	755	217	972
19 West New Britain	n/a	n/a	0	n/a	n/a	0
20 Bougainville	203	0	203	1,176	0	1,176
Region	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**
Southern	602	150	752	3,294	1,102	4,396
Highlands	511	0	511	2,378	0	2,378
Momase	679	60	739	4,199	339	4,538
islands	701	40	741	3,588	217	3,805
Altitude (m)	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**
<1200m	1,982	250	2,232	11,081	1,658	12,739
1200 to <1600	40	0	40	169	0	169
1600+ m	471	0	471	2,209	0	2,209
Age (years)				**Rural**	**Urban**	**Total**
<5				1,900	194	2,094
<1				287	23	310
1-4				1,613	171	1,784
5-9				1,989	204	2,193
10-14				1,718	190	1,908
15-19				1,356	196	1,552
20-39				3,542	504	4,046
40+				2,954	370	3,324
Sex				**Rural**	**Urban**	**Total**
Male				6,692	808	7,500
Female				6,767	850	7,617
Total	**2,493**	**250**	**2,743**	**13,459**	**1,658**	**15,117**

APPENDIX B: MOSQUITO NET COVERAGE

Table B1. Household ownership of mosquito nets

Percentage of households with at least one mosquito net (treated or untreated) and long-lasting insecticidal net (LLIN); average number of nets and LLINs per household; and percentage of households with at least one net and LLIN per two persons who stayed in the household last night, by province, Papua New Guinea, 2016-2017

Province	Percentage of households with at least one mosquito net		Percentage of households with at least two LLIN	Average number of nets per household		Percentage of households with at least one LLIN for every two persons who stayed in the household last night	Number of households with at least one person who stayed in the household last night
	Any mosquito net	LLIN[1]		Any mosquito net	LLIN		
01 Western	93.8	93.8	76.7	2.9	2.9	66.4	146
02 Gulf	92.1	91.3	81.0	3.0	2.9	61.9	126
03 Central	92.7	92.7	81.7	3.3	3.2	61.5	109
04 NCD	71.7	70.8	63.3	2.7	2.5	25.0	120
05 Milne Bay	93.0	92.2	71.3	2.3	2.3	54.8	115
06 Oro	96.3	96.3	86.0	3.1	3.0	62.5	136
08 Enga	49.2	49.2	38.1	1.1	1.1	30.2	126
09 W. Highlands & Jiwaka	62.0	62.0	49.6	1.7	1.7	43.8	137
10 Chimbu	51.7	51.7	30.3	1.0	1.0	24.8	145
11 Eastern Highlands	65.0	65.0	44.7	1.5	1.5	37.9	103
12 Morobe	90.9	90.9	76.8	3.0	3.0	66.5	164
13 Madang	94.7	94.7	89.0	3.9	3.9	62.2	209
14 East Sepik	96.0	82.5	71.0	3.4	2.7	55.5	200
15 Sandaun	88.6	84.9	59.6	2.3	2.1	44.6	166
16 Manus	98.3	98.3	86.0	3.2	3.2	78.7	178
17 New Ireland	93.6	90.2	79.8	2.8	2.6	63.6	173
18 East New Britain	82.4	82.4	67.4	2.3	2.3	50.8	187
20 Bougainville	98.0	93.6	86.7	3.7	3.4	70.9	203

[1] Green shading indicates that Global Fund target of **85%** was reached.

Table B2. Access to an LLIN

Percentage of the de facto population with access to an LLIN in the household, by province, Papua New Guinea, 2016-2017

Province	Percentage of the de facto population with access to an LLIN[1,2]
01 Western	79.4
02 Gulf	80.3
03 Central	76.4
04 NCD	55.5
05 Milne Bay	72.9
06 Oro	83.7
08 Enga	35.5
09 W. Highlands & Jiwaka	47.4
10 Chimbu	35.3
11 Eastern Highlands	52.0
12 Morobe	73.0
13 Madang	79.8
14 East Sepik	71.9
15 Sandaun	64.5
16 Manus	90.1
17 New Ireland	78.7
18 East New Britain	65.3
20 Bougainville	83.8

[1] Percentage of de facto household population who could sleep under an LLIN if each LLIN in the household were used by up to two people.
[2] Green shading indicates that Global Fund target of **70%** was reached.

Table B3. Use of mosquito nets by persons in the household

Percentage of the de facto household population who slept the night before the survey under a mosquito net (treated or untreated) and under a long-lasting insecticidal net (LLIN); and among the de facto household population in households with at least one LLIN, percentage who slept under a LLIN the night before the survey, by province, Papua New Guinea, 2016-2017

	Household population			Household population in households with at least one LLIN	
Province	Percentage who slept under any mosquito net last night	Percentage who slept under an LLIN last night[1]	Number of persons	Percentage who slept under an LLIN last night	Number of persons
01 Western	80.6	80.6	783	86.7	728
02 Gulf	78.9	77.9	660	84.5	608
03 Central	70.9	70.1	700	77.6	633
04 NCD	22.8	22.6	940	30.2	702
05 Milne Bay	55.5	55.3	553	59.1	518
06 Oro	78.6	78.6	760	81.6	732
08 Enga	11.5	11.5	575	26.0	254
09 W. Highlands & Jiwaka	28.6	28.6	696	49.3	404
10 Chimbu	21.0	21.0	680	41.7	343
11 Eastern Highlands	32.6	32.3	427	47.3	292
12 Morobe	60.3	60.3	991	69.9	856
13 Madang	77.1	77.1	1,575	81.3	1,493
14 East Sepik	78.3	65.7	1,159	79.2	962
15 Sandaun	67.0	65.1	813	79.7	664
16 Manus	52.8	52.7	825	53.4	814
17 New Ireland	34.0	34.0	832	37.6	752
18 East New Britain	36.1	36.1	972	44.5	788
20 Bougainville	48.6	48.0	1,176	50.8	1,113

[1] Green shading indicates that Global Fund target of **60%** was reached.

Table B4. Use of mosquito nets by children <5 years of age

Percentage of children under age 5 who, the night before the survey, slept under a mosquito net (treated or untreated) and under a long-lasting insecticidal net (LLIN); and among children under age 5 in households with at least one LLIN, percentage who slept under a LLIN the night before the survey, by province, Papua New Guinea, 2016-2017

	Children under age 5 in all households			Children under age 5 in households with at least one LLIN	
Province	Percentage who slept under any mosquito net last night	Percentage who slept under an LLIN last night[1]	Number of children	Percentage who slept under an LLIN last night	Number of children
01 Western	86.2	86.2	123	88.3	120
02 Gulf	83.5	80.9	115	86.9	107
03 Central	77.7	77.7	103	85.1	94
04 NCD	27.4	27.4	113	33.0	94
05 Milne Bay	75.0	75.0	80	76.9	78
06 Oro	87.9	87.9	124	91.6	119
08 Enga	10.9	10.9	55	30.0	20
09 W. Highlands & Jiwaka	34.8	34.8	92	64.0	50
10 Chimbu	32.5	32.5	80	59.1	44
11 Eastern Highlands	39.6	39.6	53	50.0	42
12 Morobe	59.2	59.2	125	67.3	110
13 Madang	78.0	78.0	236	82.1	224
14 East Sepik	83.0	69.6	171	84.4	141
15 Sandaun	76.9	73.4	143	91.3	115
16 Manus	67.4	67.4	95	69.6	92
17 New Ireland	47.3	47.3	112	51.5	103
18 East New Britain	43.8	43.8	128	54.9	102
20 Bougainville	63.0	61.0	146	62.7	142

[1] Green shading indicates that Global Fund target of **65%** was reached.

Note: Due to the small number of samples, mosquito net use in pregnant women was not calculated by province.

APPENDIX C: PARASITE PREVALENCE

Table C1. Prevalence of malaria infection

Percentage of persons above 6 months of age classified by light microscopy as having malaria, by province, Papua New Guinea, 2016-2017

	Malaria prevalence according to microscopy[1]					
Province	Any species	*P. falciparum*	*P. vivax*	*P. malariae*	Mixed *P.f.* & *P.v.*	Number of persons
01 Western	1.2	0.6	0.6	0.0	0.0	646
02 Gulf	4.0	2.8	1.6	0.0	0.3	491
03 Central	0.9	0.9	0.0	0.0	0.0	487
04 NCD	0.3	0.0	0.3	0.0	0.0	669
05 Milne Bay	10.8	5.3	5.8	0.4	0.6	427
06 Oro	5.4	3.6	2.0	0.1	0.2	598
08 Enga	0.0	0.0	0.0	0.0	0.0	361
09 W. Highlands & Jiwaka	1.3	1.3	0.0	0.0	0.0	379
10 Chimbu	0.2	0.2	0.0	0.0	0.0	429
11 Eastern Highlands	0.2	0.0	0.2	0.0	0.0	273
12 Morobe	3.4	2.6	0.8	0.0	0.0	840
13 Madang	16.0	12.3	4.8	0.1	1.1	1,387
14 East Sepik	8.8	5.6	3.4	0.1	0.2	1,006
15 Sandaun	7.9	4.3	3.3	0.6	0.4	696
16 Manus	1.5	1.0	0.5	0.0	0.0	561
17 New Ireland	8.7	4.2	4.6	0.2	0.1	584
18 East New Britain	3.9	3.2	1.1	0.0	0.4	697
20 Bougainville	0.6	0.6	0.0	0.0	0.0	827

[1] Age-standardized

Table C2. Prevalence of malaria in children <5 years of age

Percentage of children between 6 months and 5 years of age classified by light microscopy as having malaria, by province and sex, Papua New Guinea, 2016-2017

Background characteristics	Malaria prevalence according to microscopy[1]					
	Any species[2]	*P. falciparum*	*P. vivax*	*P. malariae*	Mixed *P.f.* & *P.v.*	Number of persons
01 Western	1.0	0.0	1.0	0.0	0.0	104
02 Gulf	3.3	3.3	0.0	0.0	0.0	92
03 Central	1.2	1.2	0.0	0.0	0.0	84
04 NCD	0.0	0.0	0.0	0.0	0.0	86
05 Milne Bay	17.0	5.7	11.3	0.0	0.0	53
06 Oro	7.5	4.7	2.8	0.0	0.0	106
08 Enga	0.0	0.0	0.0	0.0	0.0	17
09 W. Highlands & Jiwaka	0.0	0.0	0.0	0.0	0.0	24
10 Chimbu	0.0	0.0	0.0	0.0	0.0	36
11 Eastern Highlands	0.0	0.0	0.0	0.0	0.0	17
12 Morobe	3.2	3.2	0.0	0.0	0.0	93
13 Madang	19.6	13.2	7.3	0.0	0.9	219
14 East Sepik	13.2	5.3	7.3	1.3	0.7	151
15 Sandaun	20.5	11.5	9.8	1.6	2.5	122
16 Manus	3.0	3.0	0.0	0.0	0.0	33
17 New Ireland	13.3	1.3	13.3	0.0	1.3	75
18 East New Britain	5.7	1.9	3.8	0.0	0.0	105
20 Bougainville	1.8	1.8	0.0	0.0	0.0	113
Sex						
Female	7.9	4.5	3.1	0.6	0.4	697
Male	9.6	4.9	5.0	0.0	0.4	833
Sex (villages <1600 m)						
Female	8.6	4.9	3.4	0.7	0.4	577
Male	10.3	5.3	5.4	0.0	0.4	685

[1] Age-standardized
[2] Green shading indicates that Global Fund target of **65%** was reached.

Note: Differences in malaria prevalence observed between the mRDT and microscopy results are expected. Microscopic detection of malaria parasites depends on the visualisation of stained parasites under a microscope, whereas the diagnosis of malaria by RDT relies on the interaction between a parasite antigen present in the blood and an antibody on the mRDT. A direct comparison of results from microscopy and RDTs should therefore be avoided. The mRDT used in this survey detects the *P. falciparum*-specific, histidine-rich protein-2 (HRP-2), that can persist in the blood for up to a month after parasite clearance [34]. In areas highly endemic for *P. falciparum*, or with recent introduction or scale-up of effective treatment, the persistence of the antigen may lead to higher malaria prevalence estimates by RDTs as compared to microscopy.

Table C3. Prevalence of malaria by survey village

Percentage of persons and children < 5 years classified in two tests as having malaria, by survey village, Papua New Guinea, 2016-2017.
(Note: RDT were not performed in all provinces.)

Location			Malaria prevalence								Malaria prevalence in children < 5 years of age							
			According to RDT		According to microscopy						According to RDT		According to microscopy					
Province	Village name	Elevat. (m)	RDT positive	Number of persons	Any species	*Pf*	*Pv*	*Pm*	Mixed *Pf* & *Pv*	Number of persons	RDT positive	Number of children	Any species	*Pf*	*Pv*	*Pm*	Mixed *Pf* & *Pv*	Number of children
Western	BISUAKA SAGUANSO	3	0.7	153	0.7	0.7	0.0	0.0	0.0	153	0.0	21	0.0	0.0	0.0	0.0	0.0	21
Western	DUWINIM	470	0.0	131	0.0	0.0	0.0	0.0	0.0	132	0.0	16	0.0	0.0	0.0	0.0	0.0	17
Western	MIWA NO 2	12	0.0	173	1.1	0.6	0.6	0.0	0.0	174	0.0	41	0.0	0.0	0.0	0.0	0.0	41
Western	TAGUM	16	0.0	88	0.0	0.0	0.0	0.0	0.0	88	0.0	19	0.0	0.0	0.0	0.0	0.0	19
Western	TWANSAWANAI	26	3.0	99	4.0	1.0	3.0	0.0	0.0	99	16.7	6	16.7	0.0	16.7	0.0	0.0	6
Gulf	GIGORI	11	0.0	81	0.0	0.0	0.0	0.0	0.0	81	0.0	13	0.0	0.0	0.0	0.0	0.0	13
Gulf	HERAKELA	9	7.0	142	7.6	3.5	4.9	0.0	0.7	144	4.3	23	4.2	4.2	0.0	0.0	0.0	24
Gulf	HINENGA	35	0.0	85	1.2	1.2	0.0	0.0	0.0	83	0.0	12	0.0	0.0	0.0	0.0	0.0	11
Gulf	ILOVAPARE	3	5.6	54	9.3	9.3	0.0	0.0	0.0	54	0.0	9	11.1	11.1	0.0	0.0	0.0	9
Gulf	KAIAM 2	26	0.0	128	0.8	0.8	0.0	0.0	0.0	129	0.0	36	2.9	2.9	0.0	0.0	0.0	35
Central	AGEFA	47	0.0	26	0.0	0.0	0.0	0.0	0.0	26	0.0	3	0.0	0.0	0.0	0.0	0.0	3
Central	AROMA PRI SCH	11	0.0	106	0.9	0.9	0.0	0.0	0.0	106	0.0	23	0.0	0.0	0.0	0.0	0.0	23
Central	BEGUE SETTLEMENT	18	0.0	207	1.4	1.4	0.0	0.0	0.0	209	0.0	37	2.6	2.6	0.0	0.0	0.0	38
Central	BEREINA POPONE	17	0.0	134	0.0	0.0	0.0	0.0	0.0	84	0.0	19	0.0	0.0	0.0	0.0	0.0	12
Central	SIRINUMU DAM	599	0.0	62	0.0	0.0	0.0	0.0	0.0	62	0.0	8	0.0	0.0	0.0	0.0	0.0	8
NCD	ATS HOUSING	63	0.0	171	0.0	0.0	0.0	0.0	0.0	172	0.0	22	0.0	0.0	0.0	0.0	0.0	22
NCD	HORSECAMP SETT.	15	0.5	195	1.0	0.0	1.0	0.0	0.0	192	0.0	31	0.0	0.0	0.0	0.0	0.0	31
NCD	JACKSONS AIRP.	38	0.0	132	0.0	0.0	0.0	0.0	0.0	135	0.0	12	0.0	0.0	0.0	0.0	0.0	12
NCD	TAURAMA BARR.	15	0.0	171	0.0	0.0	0.0	0.0	0.0	170	0.0	21	0.0	0.0	0.0	0.0	0.0	21

Table C3 (continued)

Location			Malaria prevalence								Malaria prevalence in children < 5 years of age							
			According to RDT		According to microscopy						According to RDT		According to microscopy					
Province	Village name	Elevat. (m)	RDT positive	Number of persons	Any species	*Pf*	*Pv*	*Pm*	Mixed *Pf* & *Pv*	Number of persons	RDT positive	Number of children	Any species	*Pf*	*Pv*	*Pm*	Mixed *Pf* & *Pv*	Number of children
Milne Bay	GEHIGEHIYA	0	24.0	96	9.4	6.3	2.1	1.0	0.0	96	13.3	15	6.7	6.7	0.0	0.0	0.0	15
Milne Bay	LELEIAFA	32	4.5	111	4.7	1.9	1.9	0.9	0.0	107	0.0	12	0.0	0.0	0.0	0.0	0.0	12
Milne Bay	MODEWA	11	1.3	76	1.3	1.3	0.0	0.0	0.0	76	0.0	4	0.0	0.0	0.0	0.0	0.0	4
Milne Bay	ULONA	0	12.2	148	20.9	8.8	14.2	0.0	2.0	148	27.3	22	36.4	9.1	27.3	0.0	0.0	22
Oro	BASAPE	746	0.0	93	0.0	0.0	0.0	0.0	0.0	93	0.0	15	0.0	0.0	0.0	0.0	0.0	15
Oro	DAHANA BLOCK	101	1.6	127	2.4	1.6	0.8	0.0	0.0	127	0.0	17	0.0	0.0	0.0	0.0	0.0	17
Oro	KOTAURE	16	28.7	136	21.9	13.9	8.8	0.7	0.7	137	33.3	30	19.4	16.1	3.2	0.0	0.0	31
Oro	MENGOTHUTI	95	1.6	124	0.8	0.8	0.0	0.0	0.0	123	6.7	15	0.0	0.0	0.0	0.0	0.0	15
Oro	SONGDE	13	3.4	118	3.4	0.8	2.5	0.0	0.0	118	0.0	28	7.1	0.0	7.1	0.0	0.0	28
Enga	ANDITA	2410	n/a	n/a	0.0	0.0	0.0	0.0	0.0	79	n/a	n/a	0.0	0.0	0.0	0.0	0.0	9
Enga	KUNDIS	1978	n/a	n/a	0.0	0.0	0.0	0.0	0.0	50	n/a	n/a	0.0	0.0	0.0	0.0	0.0	3
Enga	MAKUKAM	2069	n/a	n/a	0.0	0.0	0.0	0.0	0.0	77	n/a	n/a	0.0	0.0	0.0	0.0	0.0	2
Enga	SOPAS ING COMP.	2198	n/a	n/a	0.0	0.0	0.0	0.0	0.0	105	n/a	n/a	0.0	0.0	0.0	0.0	0.0	3
Enga	TOMBAUK	2380	n/a	n/a	0.0	0.0	0.0	0.0	0.0	50	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0
WH/Jiwaka	BILLA	2022	n/a	n/a	0.0	0.0	0.0	0.0	0.0	41	n/a	n/a	0.0	0.0	0.0	0.0	0.0	3
WH/Jiwaka	ENAMONG	1706	n/a	n/a	0.0	0.0	0.0	0.0	0.0	49	n/a	n/a	0.0	0.0	0.0	0.0	0.0	2
WH/Jiwaka	KIA	1732	n/a	n/a	0.0	0.0	0.0	0.0	0.0	93	n/a	n/a	0.0	0.0	0.0	0.0	0.0	8
WH/Jiwaka	LASROLI	1860	n/a	n/a	0.0	0.0	0.0	0.0	0.0	113	n/a	n/a	0.0	0.0	0.0	0.0	0.0	9
WH/Jiwaka	PITI	1843	n/a	n/a	6.0	6.0	0.0	0.0	0.0	83	n/a	n/a	0.0	0.0	0.0	0.0	0.0	2
Chimbu	GUNAKOMBUIGO	2096	n/a	n/a	0.0	0.0	0.0	0.0	0.0	78	n/a	n/a	0.0	0.0	0.0	0.0	0.0	14
Chimbu	KOROKOA	1676	n/a	n/a	0.0	0.0	0.0	0.0	0.0	104	n/a	n/a	0.0	0.0	0.0	0.0	0.0	9
Chimbu	NEW CAMP	1923	n/a	n/a	2.6	2.6	0.0	0.0	0.0	76	n/a	n/a	0.0	0.0	0.0	0.0	0.0	3
Chimbu	YANDENA	2370	n/a	n/a	0.0	0.0	0.0	0.0	0.0	88	n/a	n/a	0.0	0.0	0.0	0.0	0.0	5
Chimbu	KONOMA	1922	n/a	n/a	0.0	0.0	0.0	0.0	0.0	83	n/a	n/a	0.0	0.0	0.0	0.0	0.0	5

Table C3 (continued)

Location			Malaria prevalence								Malaria prevalence in children < 5 years of age							
			According to RDT		According to microscopy						According to RDT		According to microscopy					
Province	Village name	Elevat. (m)	RDT positive	Number of persons	Any species	*Pf*	*Pv*	*Pm*	Mixed *Pf* & *Pv*	Number of persons	RDT positive	Number of children	Any species	*Pf*	*Pv*	*Pm*	Mixed *Pf* & *Pv*	Number of children
E. Highl.	ANGLNALI	1852	n/a	n/a	0.0	0.0	0.0	0.0	0.0	74	n/a	n/a	0.0	0.0	0.0	0.0	0.0	6
E. Highl.	HASMANGO	1749	n/a	n/a	1.9	0.0	1.9	0.0	0.0	52	n/a	n/a	0.0	0.0	0.0	0.0	0.0	3
E. Highl.	IPAGU PLANTATION	1472	n/a	n/a	0.0	0.0	0.0	0.0	0.0	44	n/a	n/a	0.0	0.0	0.0	0.0	0.0	1
E. Highl.	MONONUMUTO	1920	n/a	n/a	0.0	0.0	0.0	0.0	0.0	50	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0
E. Highl.	NEW CAMP	1537	n/a	n/a	0.0	0.0	0.0	0.0	0.0	53	n/a	n/a	0.0	0.0	0.0	0.0	0.0	7
Morobe	ADMIN COMP.	34	1.3	154	0.0	0.0	0.0	0.0	0.0	154	0.0	18	0.0	0.0	0.0	0.0	0.0	18
Morobe	ANGA/AFIN	315	29.3	147	19.0	14.3	4.8	0.0	0.0	147	14.3	14	7.1	7.1	0.0	0.0	0.0	14
Morobe	GAGIDU	36	0.6	181	0.5	0.5	0.0	0.0	0.0	183	0.0	15	0.0	0.0	0.0	0.0	0.0	15
Morobe	GUMBUM	1084	0.0	123	0.0	0.0	0.0	0.0	0.0	123	0.0	11	0.0	0.0	0.0	0.0	0.0	11
Morobe	MONADAMBIN	881	2.9	103	0.0	0.0	0.0	0.0	0.0	102	0.0	11	0.0	0.0	0.0	0.0	0.0	11
Morobe	MUGISUNG	58	3.1	65	1.5	1.5	0.0	0.0	0.0	131	9.1	11	8.3	8.3	0.0	0.0	0.0	24
Madang	BIL	120	5.6	195	11.7	8.2	5.6	0.0	2.0	196	3.4	29	10.3	10.3	3.4	0.0	3.4	29
Madang	DUAUG	91	15.9	226	14.9	12.7	3.5	0.0	1.3	228	9.8	51	9.4	9.4	0.0	0.0	0.0	53
Madang	GOGU	5	18.5	195	16.9	12.3	5.1	1.0	1.5	195	37.5	24	37.5	29.2	8.3	0.0	0.0	24
Madang	MATOLOI	193	6.3	160	4.4	3.8	0.6	0.0	0.0	160	0.0	28	3.6	0.0	3.6	0.0	0.0	28
Madang	REREU NO. 2	73	24.1	166	28.9	21.1	9.6	0.0	1.8	166	42.3	26	57.7	38.5	23.1	0.0	3.8	26
Madang	SILALING	105	9.0	167	12.0	6.0	6.0	0.0	0.0	167	11.5	26	19.2	3.8	15.4	0.0	0.0	26
Madang	WADAN/SAIR	0	32.4	275	28.0	22.5	7.3	0.0	1.8	275	21.2	33	15.2	9.1	6.1	0.0	0.0	33
East Sepik	ILAHIPAG	169	n/a	n/a	1.7	1.7	0.0	0.0	0.0	115	n/a	n/a	0.0	0.0	0.0	0.0	0.0	14
East Sepik	JAPARAKA	209	n/a	n/a	0.7	0.0	0.0	0.7	0.0	140	n/a	n/a	3.6	0.0	0.0	3.6	0.0	28
East Sepik	KAUYAMBE	20	n/a	n/a	35.6	29.0	8.3	0.0	1.4	146	n/a	n/a	53.3	33.3	26.7	0.0	6.7	15
East Sepik	KAMATOGU	42	n/a	n/a	15.2	4.5	10.6	0.0	0.0	132	n/a	n/a	20.8	4.2	16.7	0.0	0.0	24
East Sepik	KORO	65	n/a	n/a	3.3	1.9	1.9	0.0	0.5	210	n/a	n/a	8.3	5.6	2.8	0.0	0.0	36
East Sepik	MANDI	14	n/a	n/a	8.8	2.5	5.7	0.6	0.0	159	n/a	n/a	15.8	0.0	10.5	5.3	0.0	19
East Sepik	YAKUMBUM	469	n/a	n/a	1.9	1.0	1.0	0.0	0.0	104	n/a	n/a	0.0	0.0	0.0	0.0	0.0	15

Table C3 (continued)

Location			Malaria prevalence								Malaria prevalence in children < 5 years of age							
			According to RDT		According to microscopy						According to RDT		According to microscopy					
Province	Village name	Elevat. (m)	RDT positive	Number of persons	Any species	*Pf*	*Pv*	*Pm*	Mixed *Pf* & *Pv*	Number of persons	RDT positive	Number of children	Any species	*Pf*	*Pv*	*Pm*	Mixed *Pf* & *Pv*	Number of children
Sandaun	LAINGIU 2	540	0.0	104	0.0	0.0	0.0	0.0	0.0	118	0.0	10	0.0	0.0	0.0	0.0	0.0	12
Sandaun	MANGALI	106	74.0	131	16.0	12.2	4.6	0.0	0.8	131	95.2	21	42.9	28.6	19.0	0.0	4.8	21
Sandaun	SAMARANI	71	26.8	127	12.5	5.5	7.0	0.0	0.0	128	22.2	27	14.3	7.1	7.1	0.0	0.0	28
Sandaun	TALBIBI	543	1.0	99	0.9	0.0	0.9	0.0	0.0	113	0.0	11	0.0	0.0	0.0	0.0	0.0	16
Sandaun	WUSIPI	19	10.8	111	0.9	0.9	0.0	0.0	0.0	111	13.3	15	0.0	0.0	0.0	0.0	0.0	15
Sandaun	YUMOR 1	286	64.2	95	31.6	14.7	13.7	6.3	3.2	95	80.0	30	40.0	20.0	20.0	6.7	6.7	30
Manus	AHUS	6	0.0	104	0.0	0.0	0.0	0.0	0.0	104	0.0	3	0.0	0.0	0.0	0.0	0.0	3
Manus	ECOM. H. SCH.	0	0.0	35	2.9	2.9	0.0	0.0	0.0	35	0.0	4	0.0	0.0	0.0	0.0	0.0	4
Manus	LIAP	11	0.9	110	0.9	0.0	0.9	0.0	0.0	111	0.0	6	0.0	0.0	0.0	0.0	0.0	6
Manus	MOKORENG	18	22.2	81	3.7	3.7	0.0	0.0	0.0	81	20.0	5	20.0	20.0	0.0	0.0	0.0	5
Manus	MULIREU	11	0.0	75	0.0	0.0	0.0	0.0	0.0	76	0.0	7	0.0	0.0	0.0	0.0	0.0	7
Manus	PELIPOWAI	10	0.0	82	1.2	0.0	1.2	0.0	0.0	82	0.0	5	0.0	0.0	0.0	0.0	0.0	5
Manus	REDHILL	68	7.0	71	4.2	2.8	1.4	0.0	0.0	72	0.0	3	0.0	0.0	0.0	0.0	0.0	3
New Ireland	KAPLAMAN	14	16.2	74	21.6	8.1	13.5	0.0	0.0	74	28.6	7	28.6	0.0	28.6	0.0	0.0	7
New Ireland	KADAN	0	6.9	72	5.6	2.8	2.8	0.0	0.0	72	5.9	17	5.9	0.0	5.9	0.0	0.0	17
New Ireland	KEMBENG	0	16.9	83	8.3	8.3	0.0	0.0	0.0	84	44.4	9	0.0	0.0	0.0	0.0	0.0	9
New Ireland	LAKURUMAU	12	0.0	47	0.0	0.0	0.0	0.0	0.0	47	0.0	4	0.0	0.0	0.0	0.0	0.0	4
New Ireland	LOKON	14	21.1	90	14.6	2.2	12.4	1.1	0.0	89	42.1	19	29.4	0.0	29.4	0.0	0.0	17
New Ireland	METERAN	16	19.7	122	7.3	4.1	3.3	0.0	0.0	123	36.4	11	0.0	0.0	0.0	0.0	0.0	11
New Ireland	NONOVAUL	41	11.6	95	7.4	3.2	5.3	0.0	1.1	95	20.0	10	20.0	10.0	20.0	0.0	10.0	10
ENB	CATHOLIC MISS.	11	0.0	74	0.0	0.0	0.0	0.0	0.0	74	0.0	10	0.0	0.0	0.0	0.0	0.0	10
ENB	MAREN	39	10.5	95	7.3	4.2	3.1	0.0	0.0	96	7.1	14	6.7	0.0	6.7	0.0	0.0	15
ENB	MANDRESS STN.	16	6.4	110	9.0	6.3	4.5	0.0	1.8	111	18.5	27	10.3	0.0	10.3	0.0	0.0	29
ENB	MATUPIT 2	12	17.9	117	11.5	11.5	0.9	0.0	0.9	113	18.8	16	12.5	12.5	0.0	0.0	0.0	16
ENB	PILAPILA	14	0.0	116	0.0	0.0	0.0	0.0	0.0	116	0.0	13	0.0	0.0	0.0	0.0	0.0	13
ENB	TAGITAGI 2	219	0.0	93	0.0	0.0	0.0	0.0	0.0	95	0.0	16	0.0	0.0	0.0	0.0	0.0	16
ENB	TOWNSEND ST.	19	0.0	91	0.0	0.0	0.0	0.0	0.0	92	0.0	7	0.0	0.0	0.0	0.0	0.0	6

Table C3 (continued)

Location			Malaria prevalence								Malaria prevalence in children < 5 years of age							
			According to RDT		According to microscopy						According to RDT		According to microscopy					
Province	Village name	Elevat. (m)	RDT positive	Number of persons	Any species	*Pf*	*Pv*	*Pm*	Mixed *Pf* & *Pv*	Number of persons	RDT positive	Number of children	Any species	*Pf*	*Pv*	*Pm*	Mixed *Pf* & *Pv*	Number of children
Bougainville	BARAKO	79	0.0	101	0.0	0.0	0.0	0.0	0.0	101	0.0	21	0.0	0.0	0.0	0.0	0.0	21
Bougainville	BORIMEI	277	0.0	173	2.2	2.2	0.0	0.0	0.0	180	0.0	26	6.9	6.9	0.0	0.0	0.0	29
Bougainville	HANONG	169	0.0	72	0.0	0.0	0.0	0.0	0.0	70	0.0	4	0.0	0.0	0.0	0.0	0.0	6
Bougainville	KUKUMAI	80	0.0	83	0.0	0.0	0.0	0.0	0.0	83	0.0	6	0.0	0.0	0.0	0.0	0.0	6
Bougainville	ROROVANA	8	0.0	124	0.0	0.0	0.0	0.0	0.0	121	0.0	16	0.0	0.0	0.0	0.0	0.0	16
Bougainville	SIKARAVIRO	149	0.0	145	0.0	0.0	0.0	0.0	0.0	146	0.0	21	0.0	0.0	0.0	0.0	0.0	21
Bougainville	TARARA	12	1.6	126	1.6	1.6	0.0	0.0	0.0	126	0.0	14	0.0	0.0	0.0	0.0	0.0	14

NCD = National Capital District; WH = Western Highlands; ENB = East New Britain

APPENDIX D: MORBIDITY INDICATORS BY PROVINCE

Table D1. Fever, anaemia, severe anaemia, and splenomegaly

Percentage of persons with reported fever, acute fever, haemoglobin below the WHO threshold for anaemia and severe anaemia, and splenomegaly, by province, Papua New Guinea, 2016-2017

Province	Reported fever	Number of persons	Acute fever[1]	Number of persons	Anaemia[2]	Severe anaemia[2]	Number of persons	Splenomegaly[3]	Number of children
01 Western	1.1	644	0.7	643	73.9	1.5	644	0.0	187
02 Gulf	5.4	490	2.0	478	78.3	7.2	490	2.5	159
03 Central	1.7	536	0.0	533	65.5	3.6	536	0.7	146
04 NCD	0.0	670	0.0	659	72.0	4.8	670	0.0	148
05 Milne Bay	2.8	431	2.0	429	64.8	2.2	430	1.0	115
06 Oro	7.7	598	1.5	596	83.8	5.0	598	0.5	199
08 Enga	6.5	382	0.0	341	25.0	0.0	382	0.0	46
09 W. Highlands & Jiwaka	0.2	383	0.0	378	23.6	0.0	383	1.1	68
10 Chimbu	2.1	437	0.4	361	32.1	0.4	437	0.0	76
11 Eastern Highlands	3.0	278	1.1	245	22.3	0.6	278	0.0	42
12 Morobe	1.9	775	0.7	760	64.8	2.7	775	1.0	164
13 Madang	8.0	1384	3.3	1350	84.6	7.6	1384	2.5	402
14 East Sepik	2.2	1001	0.7	972	71.2	1.4	1001	0.0	261
15 Sandaun	3.2	702	1.2	693	92.8	12.6	702	17.8	210
16 Manus	1.5	561	0.1	547	69.7	2.6	561	0.0	113
17 New Ireland	7.2	583	1.9	570	64.6	2.9	583	3.8	150
18 East New Britain	6.3	699	1.2	493	60.5	3.1	699	0.0	168
20 Bougainville	0.3	825	1.4	817	66.1	2.2	825	0.0	201

[1] Acute fever was defined as axillary temperature >37.5°C

[2] Anaemia and severe anaemia were defined according to WHO recommendations, which include age-specific cut-offs and altitude corrections (WHO 2011).

[3] Splenomegaly was defined as a palpable spleen (i.e. Hackett grade 1 to 5) in children aged 2-9 years.

APPENDIX E: TREATMENT SEEKING BY PROVINCE

Table E1. Diagnosis, and treatment of persons with fever

Percentage of persons and children under age 5 with fever in the 2 weeks preceding the survey for whom advice or treatment was sought, outside the home, and percentage who had blood taken from a finger or heel for testing, by province, Papua New Guinea, 2016-2017.

	Persons with fever			Children under age 5 with fever		
Province	Percentage for whom advice or treatment was sought[1]	Percentage who had blood taken from a finger or heel for testing	Number of persons	Percentage for whom advice or treatment was sought[1]	Percentage who had blood taken from a finger or heel for testing	Number of children
01 Western	11.2	11.2	11	0.0	0.0	3
02 Gulf	34.8	6.3	14	0.0	0.0	2
03 Central	87.4	30.3	22	75.3	33.2	9
04 NCD	48.7	28.6	14	62.7	23.1	3
05 Milne Bay	100.0	100.0	6	100.0	100.0	1
06 Oro	27.1	18.4	30	27.4	10.2	10
08 Enga	33.3	0.0	3	100.0	0.0	1
09 W. Highlands & Jiwaka	12.0	12.0	6	n/a	n/a	0
10 Chimbu	0.0	0.0	1	0.0	0.0	1
11 Eastern Highlands	34.7	0.0	5	0.0	0.0	1
12 Morobe	100.0	83.3	3	100.0	100.0	1
13 Madang	38.8	21.1	80	40.3	18.4	12
14 East Sepik	19.0	14.3	24	24.7	16.5	13
15 Sandaun	27.8	13.7	13	56.2	56.2	5
16 Manus	80.1	80.1	2	0.0	0.0	1
17 New Ireland	79.3	47.9	9	100.0	50.0	2
18 East New Britain	49.4	32.7	16	41.1	29.8	5
20 Bougainville	59.0	22.2	13	100.0	33.8	3

[§] incl. Jiwaka
[1] Includes advice or treatment from sources outside the home.

APPENDIX F: NAMES OF CONTRIBUTORS

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