THE PMI VECTORLINK PROJECT

VECTOR CONTROL INTEGRATED DATA ANALYTICS & VISUALIZATION

BEST PRACTICES GUIDE

Recommended Citation: Burnett, Sarah, Kate Stillman, and Megan Littrell. 2021. *Vector Control Integrated Data Analytics and Visualization: Best Practices Guide*. Rockville, MD. PMI VectorLink, Abt Associates Inc.

Contract: AID-OAA-I-17-00008

Task Order: AID-OAA-TO-17-00027

Submitted to: United States Agency for International Development/PMI

Submission Date: December 31, 2021

Approved on: January 19, 2022

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VECTOR CONTROL INTEGRATED DATA ANALYTICS & VISUALIZATION

BEST PRACTICES GUIDE

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ACRONYMS

ANC	Antenatal Care
CHIRPS	Climate Hazards Center Infrared Precipitation with Station
DHS	Demographic and Health Survey
DHIS2	District Health Information Software 2
EPI	Expanded program on immunization
HMIS	Health management information system
IRS	Indoor residual spray
IRMMP	Insecticide Resistance Monitoring and Management Plan
ITN	Insecticide treated net
M&E	Monitoring and evaluation
MICS	Multiple Indicator Cluster Survey
MIS	Malaria Indicator Survey
NMCP	National Malaria Control Program
NMEP	National Malaria Elimination Programme
PBO	Piperonyl butoxide
PMI	U.S. President's Malaria Initiative
PSC	Pyrethrum spray catch
RDT	Rapid diagnostic test
WHO	World Health Organization

1. INTRODUCTION

Vector control interventions are critical to maintaining gains in malaria control and for continued progress towards elimination. Insightful use of data to inform vector control decisions can support the efficient use of resources, which can lead to high vector control coverage. The combination of various datasets is also key to developing strategies required for insecticide resistance adaptation and it can facilitate effective use of the expanded toolbox for malaria vector control as new indoor residual spraying (IRS), and insecticide treated net (ITN) products are introduced. Although evidence is critical for effective malaria vector control strategy, timely and relevant data are often not integrated and readily available to decision makers in easily accessible and actionable reports or data dashboards.

The PMI VectorLink Project has developed this vector control integrated data analytics and visualization best practices guide, based on the project's experiences, with the goal of supporting users beyond the PMI VectorLink Project to better leverage routine data sources and guide national vector control decisions. This guide is designed to support national and sub-national malaria program managers, vector control officers, monitoring and evaluation (M&E) officers, and other health sector decision-makers to use existing data sources for the planning, implementation, and monitoring of malaria vector control interventions.

The content was developed based on the PMI VectorLink Project's experiences using data integration and visualization to compile, analyze, and visualize relevant, existing data into integrated dashboards that make data more easily accessible, digestible, timely, and action-oriented (Figure I). The dashboards are developed with the use of national program and implementing partner datasets, and integrate entomological, epidemiological, intervention coverage, and climatological data, to allow in-depth review and analysis.

The guide presents specific use cases where integrated data analytics and visualizations support important malaria control decisions, including:

1. Stratification and targeting for specific vector control interventions such as IRS and ITN campaigns.
2. Optimizing implementation and coverage of vector control interventions.
3. Managing insecticide resistance through insecticide rotation.
4. Monitoring the relationship between vector control interventions, malaria burden, and vector populations.

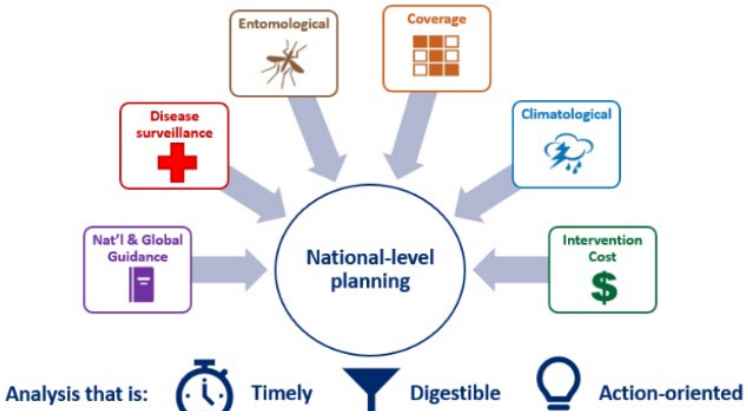


Figure 1. Integrated Data Analytics & Visualization

By documenting the project's approach, we hope to inform and engage others who are integrating data sources to guide vector control decision-making.

2. How to Use this Guide

This document provides practical examples of each of the four use cases described above: stratification and targeting; optimizing implementation and coverage; managing insecticide resistance; and monitoring the relationship between vector control interventions, malaria burden, and vector populations. These example visualizations were originally designed to support decision-making processes in specific countries and are intended to be illustrative of the ways that stakeholders can visualize vector control data. This guide contains three main sections: Use Cases, Key Indicators, and Tips and Resources.

2.1 Use Cases

The **use cases** provide an in-depth review of a specific decision-making process and how data was used. Each of the four use cases includes the following components:

- **Request:** Describes the specific decision that a national program wants to address with their data, with real-life contextual details.
- **Key Questions:** Describes the questions that the stakeholders are aiming to answer in the case study.
- **Key Indicators:** Describes the indicators used in the visualizations to help address the key questions, with a reference number that corresponds to the Key Indicators section and Annex B. Detailed Indicator Descriptions.
- **Visualizations:** Illustrative visualizations used guide the decision-making process, developed using three commonly used visualization tools: District Health Information Software 2 (DHIS2), Microsoft Excel, or Tableau.
- **Explanatory Notes:** The explanatory notes guide the visualization interpretation. The visualizations are marked with numbered boxes that correspond to the explanatory notes.
- **Decision:** Provides a brief description of the final decision that was made and how the data was used to support the decision.

Following each case study there are **quick visualizations,** alternative visualizations for each use case.

2.2 Key Indicators

The **Key Indicators** section provides brief descriptions of key malaria vector control indicators, many of which are referenced in the use cases. Where possible, these indicators were sourced from existing World Health Organization (WHO) and President's Malaria Initiative (PMI) malaria guidance documents. Here they are combined into a single source, with practical calculation and interpretation guidance to support visualization development and use. Annex B: Detailed Indicator Descriptions provides detailed definitions, data sources, and strengths, limitations and considerations for the use and interpretation of each indicator.

2.3 Tips & Resources

In the **Tips & Resources** section, we present practical recommendations for developing integrated vector control data analytics and visualizations, including how to:

- **collect and manage** the multiple data streams referenced in the use cases and indicators,
- **integrate** data sets for analyses and visualization, and
- **engage** a variety of stakeholders in data visualization design and use.

This section also offers high level guidance on the **systems, tools and staffing** that are recommended to develop visualizations like those presented in the use cases. Under **additional resources,** readers will also find links to other malaria and global health community guides that can be used to support the use of vector control data in decision-making.

3. USE CASES

3.1 STRATIFICATION & TARGETING OF INTERVENTIONS

In the context of limited resources for malaria vector control, the WHO has identified stratification as one the key strategies for improving vector control implementation (WHO, 2015a). Stratification, often carried out using a combination of malaria burden, climate, and vector species indicators, helps programs to identify the populations most greatly impacted by malaria and their malaria risk determinants, and supports appropriate targeting of malaria interventions. With well-designed stratification efforts, national programs have the potential to accelerate progress in reducing malaria transmission. In this section we provide examples of how national programs are using available data to stratify and target areas for vector control interventions.

Case Study 1: Prioritizing Regions & Districts to Receive New Types of ITNs

Request: The National Malaria Control Program (NMCP) in Mali is receiving 900,000 Interceptor G2 ITNs (IG2) for distribution. Since this is not enough nets to protect the entire population, the NMCP needs to know where they should prioritize distributing these nets, given the widespread high intensity insecticide resistance to pyrethroids throughout the country.

First, they want to prioritize a region with the highest malaria burden, which was not covered by IRS. Then within that region, they want to select districts with high burden, but that can also be completely covered by the net quantity, with some left over for use during routine net distribution for the next three years. The NMCP is also planning to formally evaluate this intervention. To support this evaluation, they want to choose districts that have ongoing entomological data collection and that are close to the Burkina Faso border, so that the evaluation results can be compared with those from a similar evaluation being conducted in Burkina Faso.

Key Questions:

- What region and districts should be prioritized for the Interceptor G2 ITNs?
- After this prioritization, how many ITNs will be available for routine distribution?

Key Indicators Used:

- 1.1.1 Malaria Parasite Prevalence
- 1.1.2 Malaria Case Incidence
- HMIS DHIS2 Estimated Population
- Estimated ITN Quantity, based on population

Visualization 1.1:
Prioritizing Regions & Districts to Receive New ITNs

1

2

Region	Rank	Malaria Case Incidence, 2018 (1.1.2)	DHS Malaria Parasite Prevalence under 5, 2018 (1.1.1)*
Sikasso	1	170.2	29.7%
Ségou	2	146.6	25.9%
Koulikoro	3	144.6	21.7%
Kayes	4	94.1	12.6%
Bamako	5	91.8	0.9%
Gao	6	91.3	15.3%
Mopti	7	83.4	24.9%
Tombouctou	8	66.8	2.9%
Menaka	9	65.9	
Taoudenit	10	17.7	
Kidal	11	16.0	1.6%

*Regions with no values were not included in the DHS 2018.

Software used: Tableau

Visualization 1.1 Explanatory Notes:

1. Malaria Case Incidence Heat Map (Indicator 1.1.2): This heat map shows the case incidence from the national HMIS for each region in 2018, ranked from highest to lowest. In this visualization the higher the case incidence the darker the color. At the time of regional decision-making this was the most recent data across both indicators.

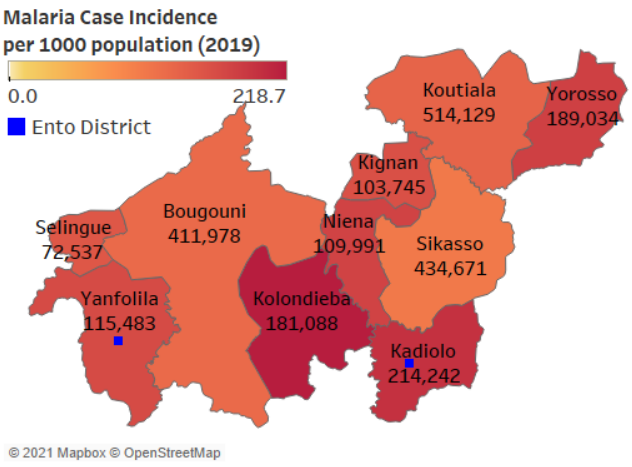
2. Malaria Parasite Prevalence Heat Map (Indicator 1.1.1): This heat map shows the malaria parasite prevalence for children under 5 years of age for the most recent 2018 Demographic and Health Survey (DHS). Two regions, Menaka and Taoudenit, did not have any data collected during the 2018 DHS. In this visualization the higher the parasite prevalence the darker the color. Looking at these values along with the malaria case incidence, we see a similar pattern with Sikasso and Segou having the highest malaria case incidence and the highest under 5 parasite prevalence for 2018. Other regions show diverging patterns. For example, Mopti has a lower malaria case incidence but a higher prevalence. This could be caused by low HMIS reporting rates, as such, additional investigations can be done to identify the reason for these divergences.

Decision: Given that Sikasso had the highest malaria case incidence and prevalence, the NMCP decided to target Sikasso for the Interceptor G2 ITNs. They then needed to choose the districts within Sikasso that would receive the ITNs.

Visualization 1.2:
Prioritizing Regions & Districts to Receive New ITNs

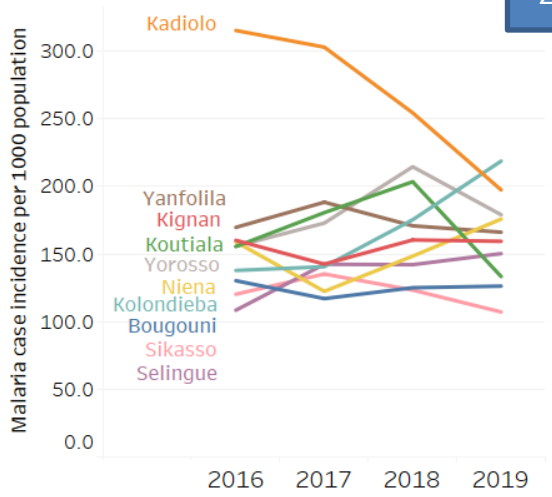
1

Districts, by ITN estimated quantity & malaria case incidence, 2019



2

Malaria Case Incidence, by region and year



Malaria Case Incidence per 1000 population, ITN estimated quantity, and estimated population

3

District	Malaria case incidence per 1000 population 2019	Estimated population 2021 (DHIS2)	Estimated ITN quantity 2021 (DHIS2)	Running Sum of ITN estimated quantity 2021 (DHIS2)
Kolondieba	218.7	296,326	181,088	181,088
Kadiolo	197.4	350,577	214,242	395,330
Yorosso	179.0	309,328	189,034	584,364
Niena	175.8	179,985	109,991	694,354
Yanfolila	166.1	188,972	115,483	809,837
Kignan	159.4	169,765	103,745	913,582
Selingue	150.3	118,696	72,537	986,119
Koutiala	133.3	841,301	514,129	1,500,248
Bougouni	126.3	674,146	411,978	1,912,226
Sikasso	107.1	711,281	434,671	2,346,897
Grand Total	1,613.5	3,840,378	2,346,897	2,346,897

Software used: Tableau

Visualization 1.2 Explanatory Notes:

1. Districts by Estimated ITN Quantity and Malaria Case Incidence (Indicator 1.1.2): This map shows the case incidence for each district for 2019, the most recent year of data at the time of district-decision-making. In this visualization the higher the case incidence the darker the color. Each district is labeled with the name of the district and the estimated number of ITNs required. The number of ITNs required was estimated as the total population in the HMIS divided by 1.8, per WHO estimation guidance, and multiplied by 1.10 to account for a 10% buffer stock (WHO, 2019). The districts where entomological data was already being collected were also added to the map. The NMCP wanted to be sure that IG2 ITNs were distributed in districts that already had entomological baseline data so they could monitor the impact of the IG2 ITNs on local vector populations.

2. Malaria Case Incidence, by district and year (Indicator 1.1.2): This line graph shows the malaria case incidence for each district from 2016-2019. This was added to the visualization because we wanted to observe the historical trends in case incidence. This would make sure that if we are choosing districts in part based on districts having the highest burden, that this trend in burden was consistent over time.

3. Malaria Case Incidence (Indicator 1.1.2), estimated population, and estimated ITN quantity. This heatmap shows the district malaria case incidence in table form, beside the estimated population from the HMIS, and the estimated quantity of ITNs required to protect the population. The final column provides a running sum of the total number of ITNs required. In this interactive visualization the NMCP staff were able to reorder the districts in the dashboard to pick their top priority districts. In this case the four priority districts selected were Kadiolo, Yorosso, Yanfolila and Selingue.

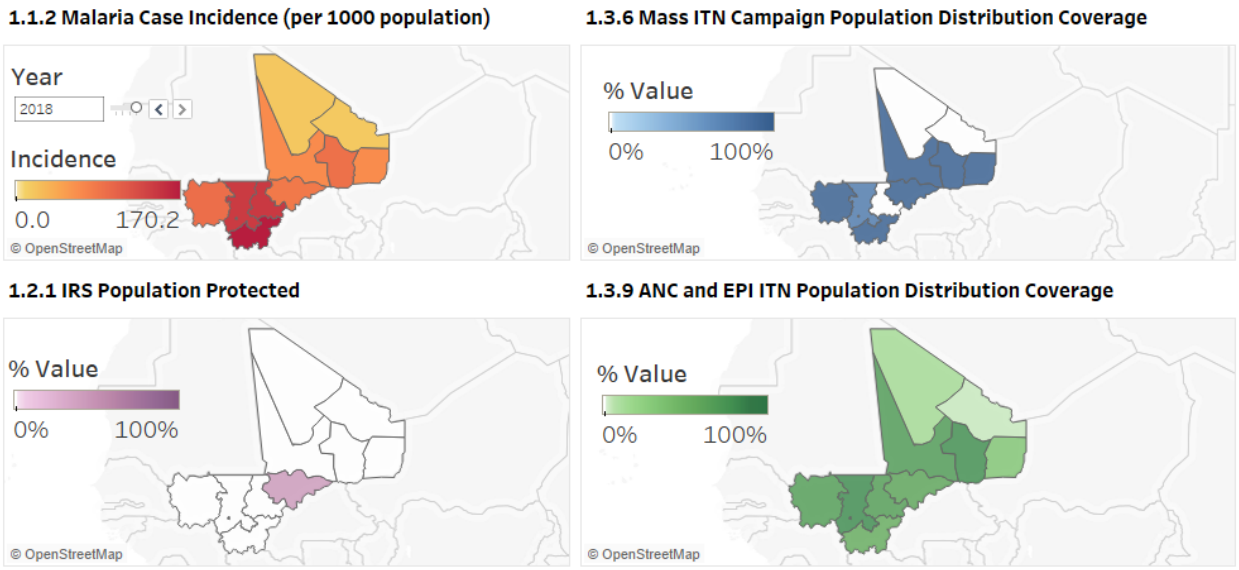
Decision: The NMCP selected four districts to receive IG2 ITNs:

- Kadiolo due to its high malaria burden, entomological site, and border with Burkina Faso, which would be useful when comparing Mali and Burkina Faso IG2 ITN evaluation results.
- Yorosso due to its high burden and shared Burkina Faso border.
- Yanfolila because of its entomological site.
- Selingue because it was a small district that could easily be covered with the remaining IG2 ITNs available and contiguous with Yanfolila, which would facilitate an easier distribution process.

An estimated 591,295 IG2 ITNs were required for these four districts, leaving the NMCP with roughly 300,000 IG2 ITNs for use during routine antenatal care (ANC) and expanded programme on immunization (EPI) distribution in these targeted districts in the coming years, to sustain high coverage with the new type of ITN.

Stratification & Targeting of Interventions: Quick Visualizations

Quick Visualization 1. Malaria case incidence (Indicators 1.1.2) and vector control coverage, by intervention type (Indicators 1.2.1, 1.3.6, 1.3.9) and region, Mali



White areas in maps indicate areas not protected by the intervention. For Mass ITNs Campaign, the white areas show regions that did not receive ITNs in the three years prior to the selected year. For IRS, the white areas show regions that did not receive IRS in the selected year.

Region	Malaria Case Incidence (per 1000)	Mass ITN Campaign Population Distribution Coverage	ANC and EPI ITN Population Distribution Coverage	IRS Population Protected
Sikasso	170.2	98%	54%	
Ségou	146.6		66%	
Koulikoro	144.6	76%	80%	
Kayes	94.1	97%	67%	
Bamako	91.8		68%	
Gao	91.3	97%	79%	
Mopti	83.4	97%	60%	43%
Tombouctou	66.8	97%	69%	
Menaka	65.9	97%	33%	
Taoudenit	17.7		14%	
Kidal	16.0		4%	

- A dashboard, like the one above, could be used to review the coverage of vector control interventions alongside malaria case incidence (Indicator 1.1.2). This example includes three key vector control intervention indicators, mass ITN campaign distribution coverage (Indicator 1.3.6), ANC and EPI ITN population distribution coverage (Indicator 1.3.9) and IRS population protected (Indicator 1.2.1). Additional interventions, such as seasonal malaria chemoprevention, can also be included. Dashboards like this can help to prioritize areas for future interventions. For example, one can see that there has been no mass ITN campaign within the past three years in Segou, which has the second highest malaria case incidence among all the regions. In Mali, ITN campaigns are rotated so that some regions receive ITNs each year, with the goal of each region receiving ITNs every three years. This region could be prioritized for a future mass campaign. In each of the maps, as in the table, the darker color indicates a higher percentage coverage. Users could also choose other indicators from this guide to include in a dashboard like this, such as ITN population distribution coverage through all channels (Indicator 1.3.10).

3.2 Optimizing Implementation & Coverage

Vector control programs require the mobilization of a great number of staff, commodities, and funding for successful implementation. Using integrated visualizations before, during, and after program implementation can help ensure that these resources are optimized to improve implementation processes and program coverage. Visualizations can be used to plan across vector control interventions, monitor ongoing implementation to identify potential gaps and, and to review coverage post-campaign and support future strategy development. In this section we provide examples of national programs using integrated data to optimize vector control implementation and coverage.

Case Study 2: Monitoring ITN & IRS Campaign Coverage

Request: The National Malaria Elimination Programme (NMEP) in Zambia is shifting to a new system of universal vector control coverage with either ITNs or IRS within each health facility catchment area, with allowance for a 10% overlap. The NMEP wants to be able to track coverage of each intervention and to identify any gaps in coverage.

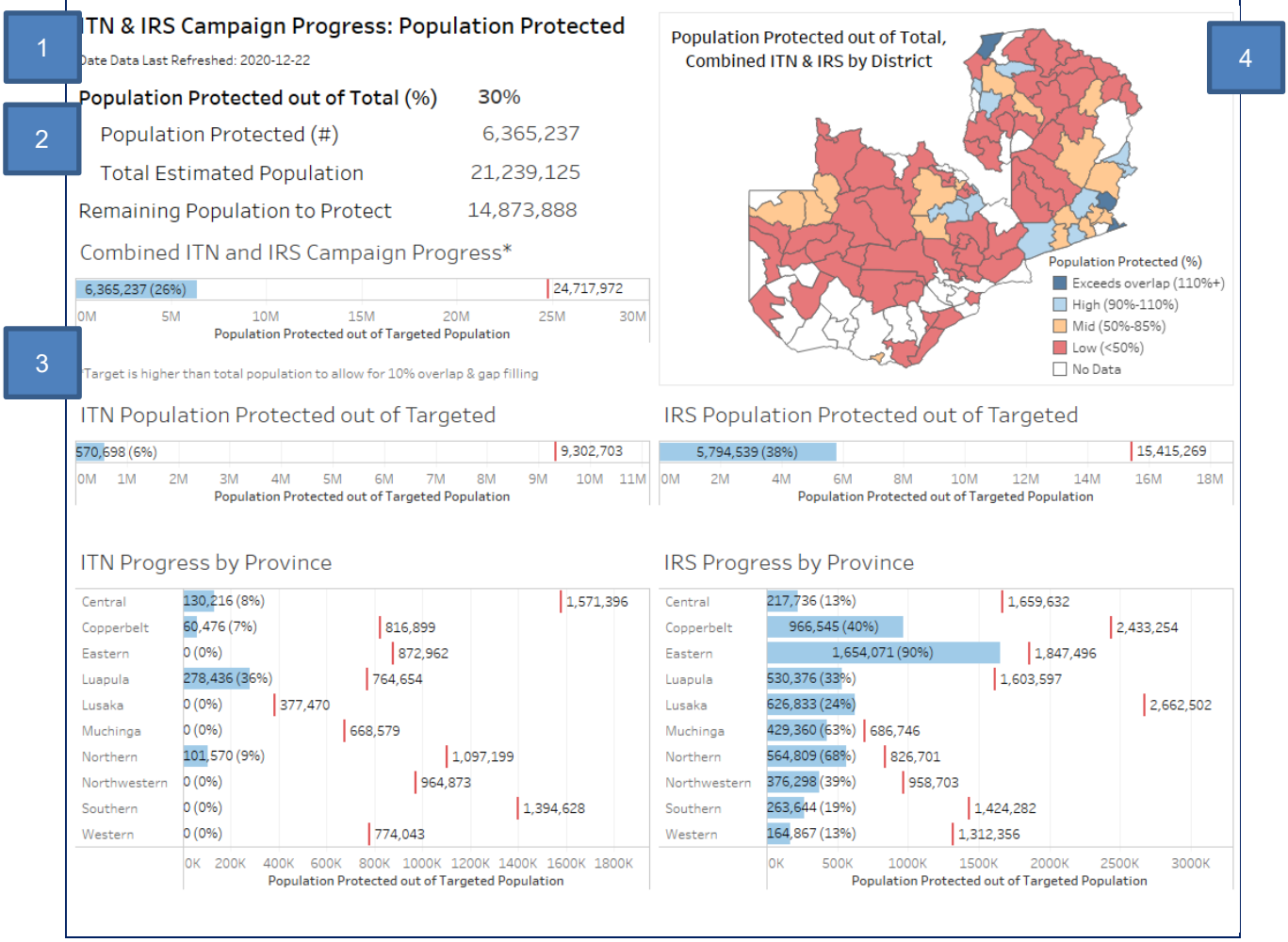
Key Questions:

- What areas are being protected through the current vector control campaigns?
- Where are there still gaps in coverage?

Key Indicators Used:

- 1.2.1 IRS population protected
- 1.3.6 Mass ITN campaign distribution coverage

Case Study Visualization 2.1: Monitoring ITN & IRS Campaign Coverage



Visualization 2.1 Explanatory Notes:

1. Date last refreshed: Including the date last refreshed provides useful context for dashboards used to monitor an on-going campaign. Dashboards like this can be refreshed as often as users need to review the data, on a weekly, daily or real-time basis.

2. Population Protected out of Total: These top-level national indicators show the current estimated population protected by ITN and IRS programs. It provides the current estimated population protected as a percent of the total estimated population. The population protected across ITN and IRS programs is calculated by combining IRS population protected (Indicator 1.2.1) and mass ITN campaign distribution coverage (Indicator 1.3.6). The difference between the estimated population protected and the total is the remaining population to protect.

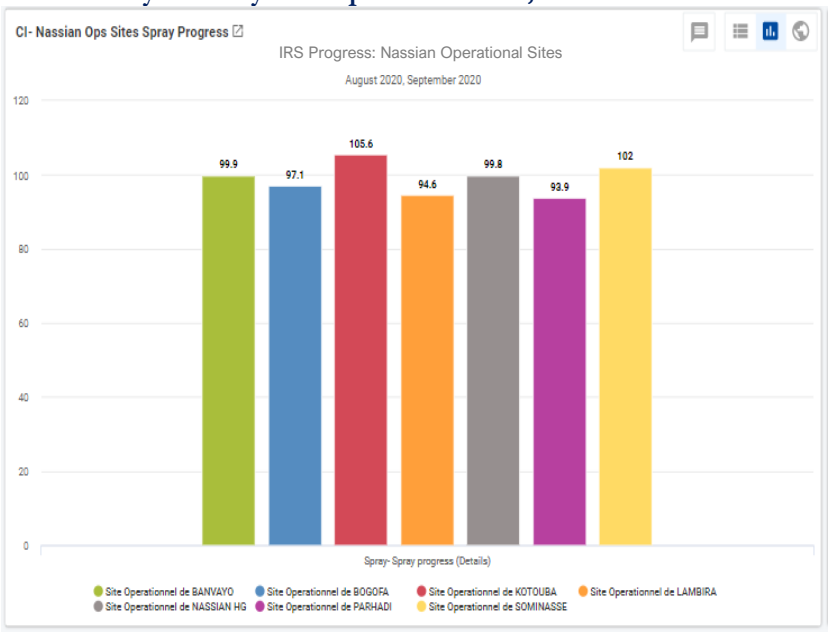
3. ITN & IRS Population Protected out of Targeted: These indicators are a variation of IRS population protected (Indicator 1.2.1) and mass ITN campaign distribution coverage (Indicator 1.3.6). In the case of Zambia, sub-health facility locations, called zones, were targeted for either ITNs or IRS, with an allowed 10% overlap. The population targeted through these campaigns is higher than the total population, to allow for

some overlap. Using these horizontal bar charts with embedded targets, national staff can quickly view progress at the national and province level by program.

4. Population Protected out of Total, by District: This map shows the combined ITN and IRS estimated population protected by district. The colors of each district indicate the districts' progress towards the target, whether coverage exceeds the expected 10% overlap (exceeds overlap) is high (85%-100%), mid (50%-85%), low (<50%), or if there is no data. As the campaign progresses, we would expect the districts to move from white (no data) to red (low coverage) to light blue (high coverage). Including districts with no data can indicate where campaigns have yet to start, or where data has not yet been entered. This visualization provides useful information for following-up on progress at the district level.

Optimizing Implementation & Coverage: Quick Visualizations

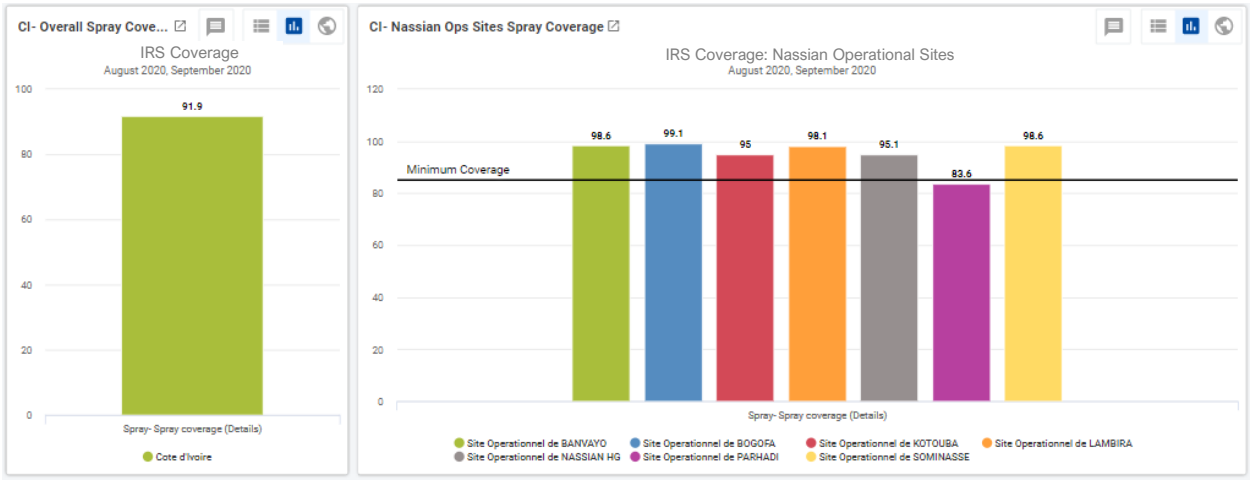
Quick Visualization 2. IRS Progress (Structures Sprayed out of Targeted) (Indicator 1.2.3), by Country and Operational Site, Cote d'Ivoire



Software used: DHIS2

- This visualization shows the IRS progress towards the targeted number of structures by operational site, which is a sub-district unit used to coordinate the IRS campaign. It is useful to have IRS progress coverage data disaggregated by operational units and at the lowest geographic level possible, such as a health facility or a sub-health facility level. This will support ensuring that each identifiable unit meets standards for IRS coverage.
- Notice that some operational sites have IRS coverage greater than 100%. Targeted structures are often estimates based on calculations from population, geospatial estimates, or ground enumeration. It is not uncommon to have values greater than 100%. However, if IRS progress is much higher than 100% that may cause you to question the accuracy of the estimation used. Sometimes it may be helpful to compare IRS progress using more than one data source for structure estimation. For example, one could compare structure estimates from geospatial structure counts to structures estimates derived by dividing the estimated population by an average number of people per structure.

Quick Visualization 3. IRS Coverage (Structures Sprayed out of Found) (Indicator 1.2.2) by Country and Operational Site, Cote d'Ivoire



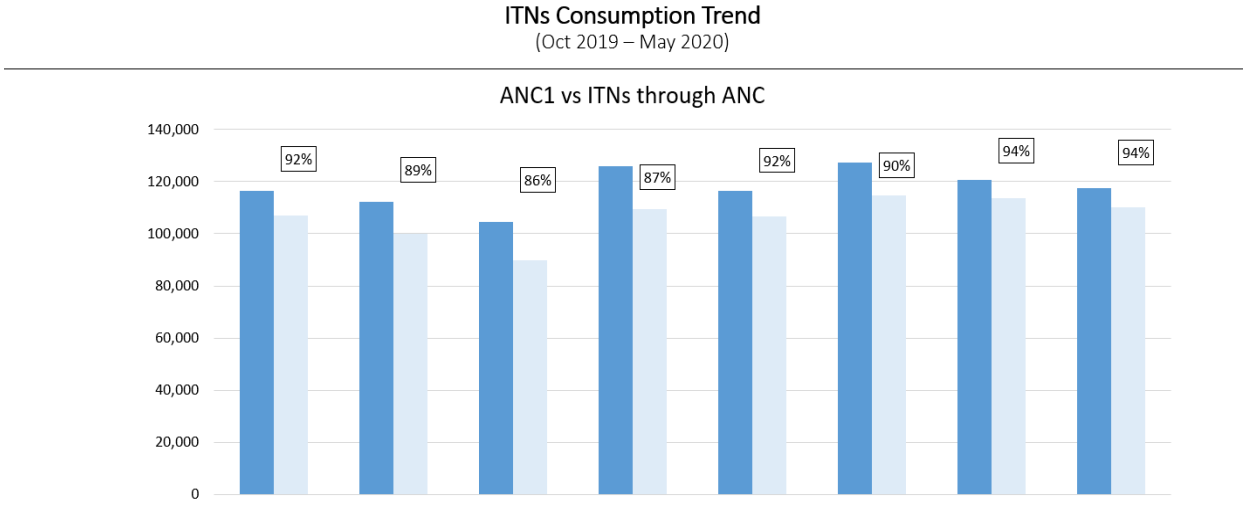
Software used: DHIS2

- WHO recommends that IRS teams spray at least 80% of eligible houses, structures, or units within targeted areas. Some programs may choose a target above the minimum recommendation of 80%, such as in this example where the coverage target was set to 85%.
- A key indicator to monitor IRS coverage is structures sprayed out of the structures found. IRS coverage tells you whether the spray operators sprayed most of the structures they found and whether the coverage target was met. However, depending on the type of terrain of the area, there may be structures that the spray operator does not find because they are in pockets of isolated structures that may be difficult to access due to the terrain.
- In Quick Visualization 3 above, overall IRS coverage for all areas targeted for IRS is shown, alongside a breakdown by operational site. This type of visualization offers important insights into an IRS campaign during its implementation. A reference line for minimum coverage is included, which shows that at the time this chart was generated all but one operational site met the target. This may prompt operational decisions to achieve the target in this operational site before the end of the IRS campaign.

Quick Visualization 4. Combining IRS Coverage (Indicator 1.2.2) & IRS Progress (Indicator 1.2.3), by District and Health Facility, Bandiagara, Mopti

- Looking at IRS coverage and IRS progress together and over time for a given area can also tell you more about the program operations. In this visualization the average IRS coverage by district is the blue bar and each red circle is a health facility.
- In this example, the IRS coverage, structures sprayed out of found, in Bandiagara was at or above 96% for each year, and only one health facility catchment area (red circle) fell below the 85% target in 2018. This indicates that in the areas that the spray operators reached they were successfully spraying structures.
- IRS progress, structures sprayed out of targeted, varied from a low of 69% in 2018 to 107% in 2019. During the 2018 campaign, the spray team identified an increased number of rooms eligible for spraying per house. The gap between IRS progress and the IRS coverage could indicate either that the estimate of the targeted structures was too high or that not all structures were reached. This should prompt additional discussion among program staff and comparison of total structures counts across years.

Quick Visualization 5. ANC1 ITN distribution coverage (Indicator 1.3.7), October 2019-May 2020



	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20
# of ANC1 Clients	116,491	112,373	104,421	125,850	116,341	127,251	120,539	117,333
# of ITNs through ANC	107,096	99,973	89,916	109,408	106,461	114,733	113,510	110,005
% Reach (ANC)	92%	89%	86%	87%	92%	90%	94%	94%

Software used: Excel

- This graph shows distribution of ITNs during first antenatal (ANC1) visits within a country. The bars show the number of ANC1 clients and the number of ITNs distributed through ANC, per month. The data table below the graph provides a quick reference in case a user needs to know the precise number of ITNs. A visualization like this can be used on a monthly basis to track to continuous ITN distribution and identify if coverage falls below a pre-determined target.

3.3 MANAGING INSECTICIDE RESISTANCE

Reductions in malaria cases and deaths over the past 20 years are under threat due to the spread of insecticide resistance, rendering traditional vector control products less effective in the fight against malaria. To address this growing risk, the global community is developing new insecticides and vector control products. WHO has also provided updated guidance on the use and rotation of existing and new products to ensure that the effects of insecticide resistance are mitigated. Visualizations can support programs to manage the increasing complexity of multiple IRS and ITN product deployments across geographical areas and years. In this section we provide examples of how national programs are using integrated visualizations to manage insecticide resistance and appropriate use of new insecticides.

Case Study 3: IRS Product Choice in Zambia

Request: The Insecticide Resistance Monitoring and Management Plan (IRMMP) Technical Advisory Committee in Zambia was asked to make a recommendation to the NMEP on which insecticide to use for IRS in each district for the 2020 campaign.

Key Questions:

- Which districts have documented resistance to each IRS active ingredient?
- Which IRS product should be recommend for use in each district, based on resistance, residual efficacy, the predominant species in each location, and product rotation

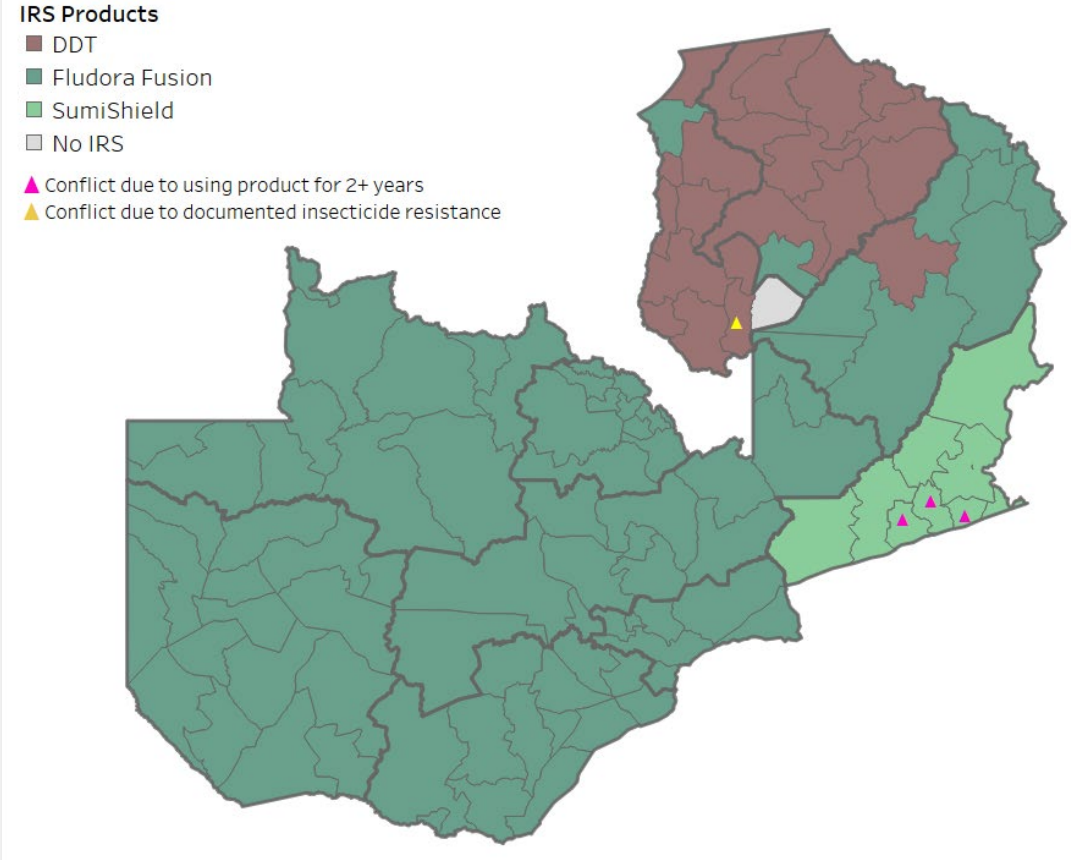
Key Indicators Used:

- IRS Product History
- 1.4.1 Vector Density
- 1.5.1 Insecticide susceptibility
- 1.6.2 IRS insecticide residual efficacy months

Visualization 3.1:
IRS Product History (2019) & Product Choice Conflicts

1

2



Visualization 3.1 Explanatory Notes

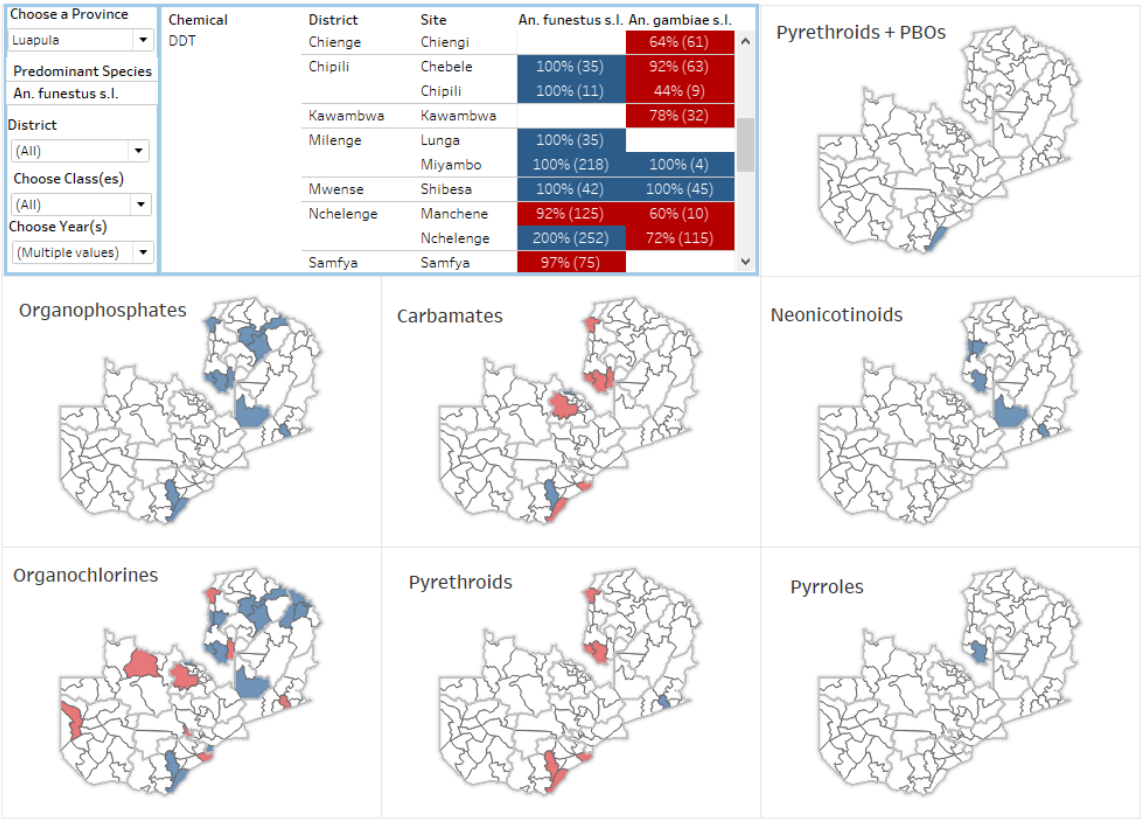
1. IRS Product History: The map shows the IRS products that have been used in the province in the previous year. Based on the NMEP IRMMP, insecticides should be rotated every two years.

2. Product Choice Conflicts: The pink triangles on the map flag districts where the same product was used for the previous two years and a change is recommended. The IRMMP also recommends discontinuing the use of an insecticide if there is documented resistance within the previous two years. The yellow triangles indicate districts where insecticide susceptibility samples have identified resistance to the current insecticide being used.

Visualization 3.2:
Insecticide Susceptibility, by District, Predominant Species, Chemical Class, and Year

1

3



Visualization 3.2 Explanatory Notes

1. **Choose filter settings:** This visualization allows you to filter the table for the province, district, chemical class and years of interest. When the province is chosen, the predominant species for the province is revealed. The NMEP defines the predominant species as the *Anopheles* vector that comprises 90% or greater of the vector density between *Anopheles funestus* s.l. and *An. gambiae* s.l. These filters allow users to focus their investigation on the districts and chemical classes they are interested in. In this example, multiple years were chosen.

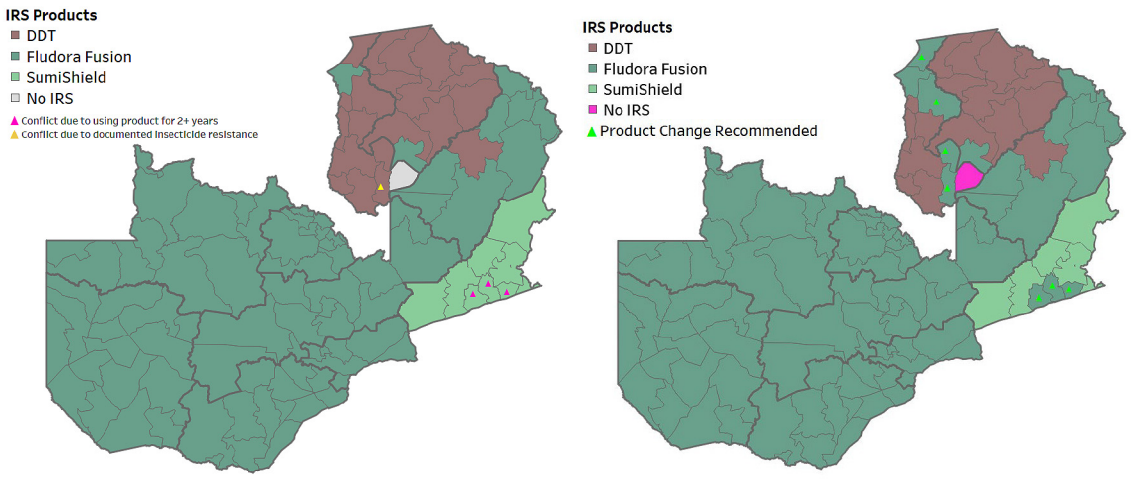
2. **Insecticide Susceptibility (Indicator 1.5.1) Detail:** The insecticide susceptibility detail table shows all the insecticide susceptibility test data that are available given the filter settings. For each province and chemical class, the data is presented by chemical, district, site, and species (*An. funestus* s.l. and *An. gambiae* s.l.). If there are more samples than can be shown in the window a grey bar appears on the right to scroll through the available data.

3. **Insecticide Susceptibility (Indicator 1.5.1) Map:** There is one map for each chemical class with available insecticide susceptibility data. In each of the maps, the provinces are colored by the lowest susceptibility percentage from the most recent sample with the filtered years obtained within each district. The maps are useful complement to the table in that they show spatially where the insecticide

susceptibility data is available, and where there are gaps. There is also built-in interactivity so that when a district is selected in the table, it is highlighted on the maps for each chemical class.

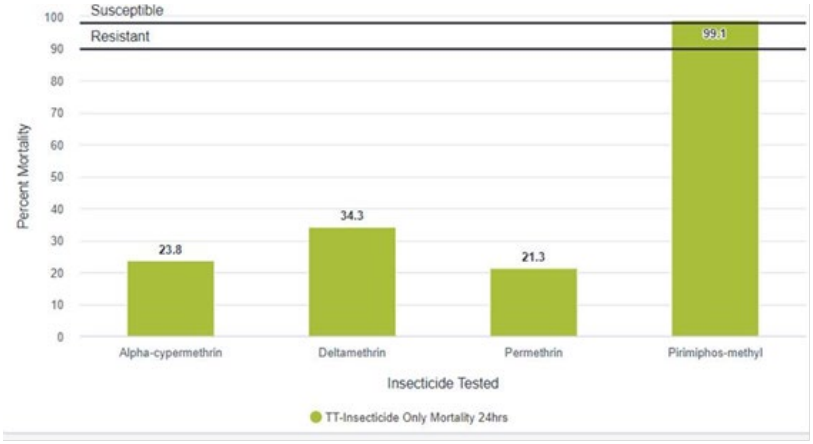
Decision: Based on the data review, the IRMMP Technical Advisory Committee recommended product changes in districts that had used the same product for the previous two years, and in districts which had documented resistance to the product within the district or within a neighboring district. Actellic® 300CS (active ingredient: pirimphos-methyl) was not considered due to the documented short residual efficacy (an average of 4 months with over 80% mosquito mortality). The map, 2020 Recommendation, below, shows the committee's final recommendation for the 2020 IRS campaign. The green triangles on select districts indicate the districts where a product change was recommended. This was used by the NMEP to inform their final IRS product choice decision. As both Fludora Fusion and SumiShield contain the active ingredient clothianidin, PMI does not consider changing between these two products as an insecticide rotation. However, given the lack of other viable options, the TWG decided to switch from SumiShield to Fludora Fusion.

2019 Implementation	2020 Recommendation



Managing Insecticide Resistance: Quick Visualizations

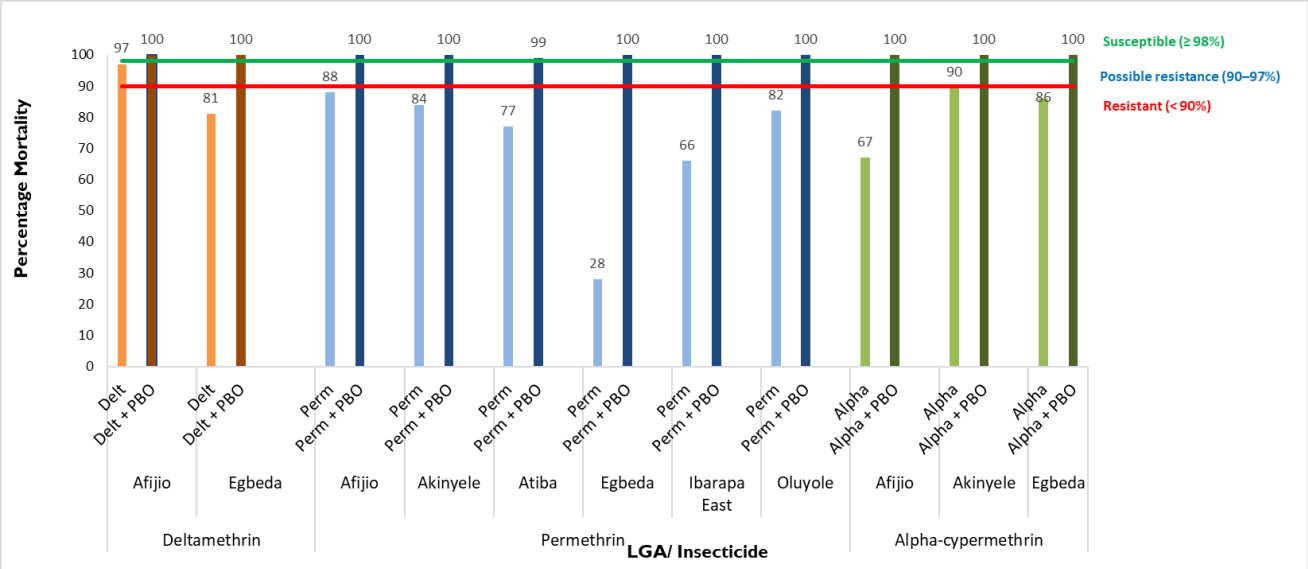
Quick Visualization 6. Percent mortality of *An. gambiae* s.l. tested against insecticides at 24 hours, WHO Tube Test (Insecticide susceptibility, Indicator 1.5.1)



Software used: DHIS2

- This graph, created in DHIS2, shows the insecticide susceptibility for four insecticides for a given site. This visual includes reference lines for the susceptibility (≥ 98%) and confirmed resistance (< 90%), with the area between them indicating possible resistance (90–97%).

Quick Visualization 7. Synergist Bottle Assay Results for *An. gambiae* s.l. (Insecticide susceptibility, Indicator 1.5.1), Oyo State, Nigeria



Software used: Excel

- This graph shows the insecticide susceptibility for various pyrethroids and each pyrethroid when paired with piperonyl butoxide (PBO) synergist, by local government area (LGA). This information can be useful to identify the pyrethroids active ingredient and location where the PBO synergist restores susceptibility. This can inform recommendations on PBO ITNs procurement and distribution.

Quick Visualization 8. Insecticide Susceptibility (Indicator 1.5.1) and Resistance Intensity (Indicator 1.5.2), 8 sites, Cote d'Ivoire

Insecticide Tested	Abengourou	Aboisso	Adzopé	Béoumi	Bettié	Bouaké	Bouna	Daloa
	Number Tested (% mortality)	**Number Tested (% mortality)**	**Number Tested (% mortality)**	**Number Tested (% mortality)**	**Number Tested (% mortality)**	**Number Tested (% mortality)**	**Number Tested (% mortality)**	**Number Tested (% mortality)**
Deltamethrin (0.05%) 1x	90 (0)	84 (6)	91 (0)	76 (6.6)	97 (10.3)	100 (0)	86 (9.3)	95 (1.1)
PBO + deltamethrin (0.05)	89 (14.6)	84 (56)	91 (49.5)	73 (80.8)	94 (44.7)	95 (57.9)	95 (71.6)	85 (10.6)
Deltamethrin (0.25%) 5x	104 (27.9)	84 (11.9)	91 (53.1)	89 (75.3)	99 (31.3)	62 (38.7)	85 (18.8)	93 (22.6)
Deltamethrin (0.5%) 10x	99 (45.5)	80 (57.5)	91 (68.1)	73 (79.5)	107 (61.3)	97 (49.5)	85 (51.8)	89 (33.7)
Permethrin (0.75%) 1x	94 (1.1)	84 (0)	96 (2.1)	83 (0)	98 (1)	95 (2.1)	96 (7.3)	91 (1.1)
PBO + permethrin (0.75%)	89 (4.5)	84 (10.7)	95 (14.7)	77 (6.5)	100 (8)	93 (19.4)	101 (53.5)	93 (11.8)
Permethrin (3.75%) 5x	109 (42.2)	95 (17.9)	92 (27.2)	84 (63.1)	98 (67.3)	87 (37.9)	90 (60)	95 (11.6)
Permethrin (7.5%) 10x	97 (62.9)	97 (64.9)	95 (60)	74 (95.9)	100 (80))	101 (57.4)	90 (88.9)	86 (40.7)
Alpha-cypermethrin (0.05) 1x	90 (0)	81 (0)	91 (4.4)	88 (4.5)	105 (1.9)	106 (4.7)	93 (2.2)	93 (4.3)
PBO + alpha-cypermethrin (0.05)	77 (3.9)	84 (83.3)	97 (26.8)	83 (53)	105 (73.5)	103 (44.7)	96 (21.9)	93 (9.7)
Alpha-cypermethrin (0.25) 5x	93 (18.3)	80 (16.3)	86 (10.5)	80 (46.3)	100 (15)	88 (14.8)	93 (11.8)	95 (9.5)
Alpha-cypermethrin (0.5) 10x	100 (43)	80 (21.3)	97 (21.6)	75 (77.3)	95 (48.4)	101 (42.6)	96 (16.7)	91 (23.1)
Lambdacyhalothrin (0.05%) 1x	103 (0)	x	x	84 (54.8)	100 (99)	78 (0)	89 (2.2)	91 (38.5)
Bendiocarb (0.1%) 1x	95 (50.5)	98 (1)	89 (53.9)	x	88 (60.2)	78 (11.5)	98 (50)	96 (1)
Bendiocarb (1%) 10x	94 (77.7)	x	x	x	x	91 (37.4)	100 (64)	x
Pirimiphos-methyl (0.25%) 1x	105 (100)	97 (73.2)	98 (90.8)	86 (100)	101 (25.7)	84 (100)	98 (100)	97 (34)
Pirimiphos-methyl (1.25%) 5x	x	95 (100)	99 (100)	x	97 (100)	x	x	92 (100)

[x] *represents the tests that were not completed, either because not enough mosquitoes were collected or because these mosquitoes were not needed for the intensity assay.*

Resistance confirmed *Suspected resistance* *Susceptible*

Software used: Excel/Word

- This table presents a heat map combining insecticide susceptibility and insecticide resistance intensity results. The table is color coded to easily identify which products remain effective against mosquito populations within each site. The table also provides the number of mosquitoes collected as a measure of quality, as WHO recommends that at least 100 mosquitoes are included in each sample. With the white boxes filled with "X"s the table also highlights areas where information is missing. Based on this visual it is easy to identify that there is widespread resistance with high intensity across pyrethroids and bendiocarb. The vector's susceptibility was not restored after pre-exposure to PBO, and this might indicate that PBO nets are not an option to manage the intense and widespread pyrethroid resistance in these areas. Pirimiphos-methyl is the one active ingredient that has maintained susceptibility at several sites, however some sites are also showing resistance.

3.4 Monitoring the Relationship Between Vector Control Interventions, Malaria Burden, and Vector Populations

The goal of any vector control intervention is to reduce the population of malaria vectors in order to ultimately reduce the malaria burden in human populations. While formal evaluations with statistical analyses are required to document the impact of vector control interventions, reviewing integrated data to monitor the relationship between vector control program and key epidemiological and entomological outcome measures can help programs to explore potential effects of vector control interventions and support the evaluation design. In this section we provide examples of how national programs are using integrated visualizations to monitor the relationship between vector control interventions, malaria burden, and vector populations.

Case Study 4: Monitoring the Relationship between IRS and Malaria Case Incidence in Mali, 2016-2018

Request: The NMCP in Mali wants to know how effective IRS in Mali has been since the switch from the Segou to the Mopti region in 2017.

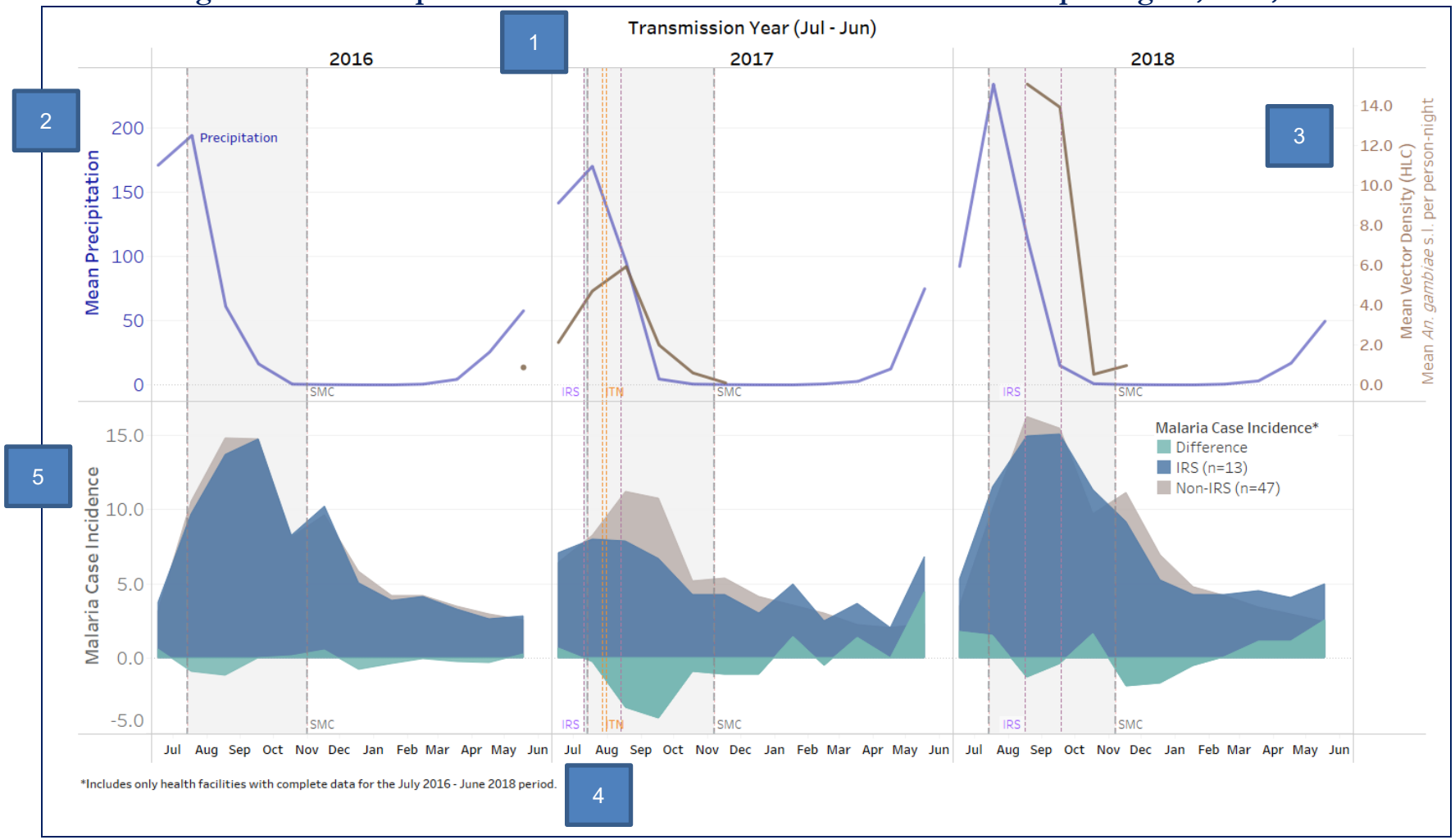
Key Questions:

- What is the relationship between IRS implementation and malaria burden?
- What is the relationship between IRS implementation and vector density?

Key Indicators Used:

- 1.1.2 Malaria Case Incidence
- 1.4.1 Vector Density
- 1.7.1 Precipitation
- IRS & ITN program implementation timing

Case Study Visualization 4.1:
Monitoring the Relationship between IRS and Malaria Case Incidence in Mopti Region, Mali, 2016-2018



Case Study Visualization 4.1 Explanatory Notes:

1. Transmission Year: In this dashboard the trends are observed based on the transmission year. In this case study, Mali's transmission year is presented, which is from July to June the following year. The transmission year is defined by observed trends in case incidence and begins when cases first start to increase. In this example, the 2016 transmission year runs from July 2016 to June 2017. The transmission year is preferable to a calendar year because the impact of a vector control intervention such as IRS that targets a season may have an impact that spans two calendar years. In some cases, it may be appropriate to use the post-IRS period of IRS insecticide residual efficacy, rather than the full transmission year, when assessing the impact of IRS on malaria case incidence.

2. Mean Precipitation (Indicator 1.7.1): This line graph shows the mean precipitation for the entire Mopti Region. This region is where IRS was implemented in Mali during the 2017 and 2018 transmission season. In this visualization we can see that mean precipitation, as measured in millimeters, was lowest in 2017 and highest in 2018.

3. Mean Vector Density (Indicator 1.4.1): This line graph shows the mean vector density from the four entomological monitoring sites in the Mopti Region. In Mali, entomological monitoring is only done during the high transmission season. We were not able to compare mean vector density by IRS and non-IRS sites as all the entomological monitoring sites were located within the catchment areas of health facilities that received IRS. The mean vector density trends in 2017 and 2018 follow a similar pattern as is seen in the mean precipitation. There is lower vector density in 2017 when precipitation is lower, and higher vector density in 2018 when precipitation is higher.

4. IRS, ITN and SMC implementation period: These purple, orange and grey reference bands show the time period in which IRS, ITN mass campaigns and SMC campaigns were implemented. SMC occurred between July to November in all three years, 2016-2018 in all districts. In 2017 the IRS campaign started at the end of July and ended near the end of August. The ITN mass campaign took place during the IRS campaign in mid-August in all districts. In 2018, there was no ITN mass campaign and the IRS campaign took place later in the year, during September.

5. Malaria Case Incidence (Indicator 1.1.2): This graph shows the malaria case incidence by month for facilities in areas that received IRS (blue) and did not receive IRS (grey) during the 2017 and 2018 period, compared to 2016, the year before IRS implementation. The difference between the two curves is shown in green. In months when there was lower case incidence in the areas that received IRS, the green area is the below the line. In months when there was higher case incidence in the areas that received IRS, the green area is the above the line.

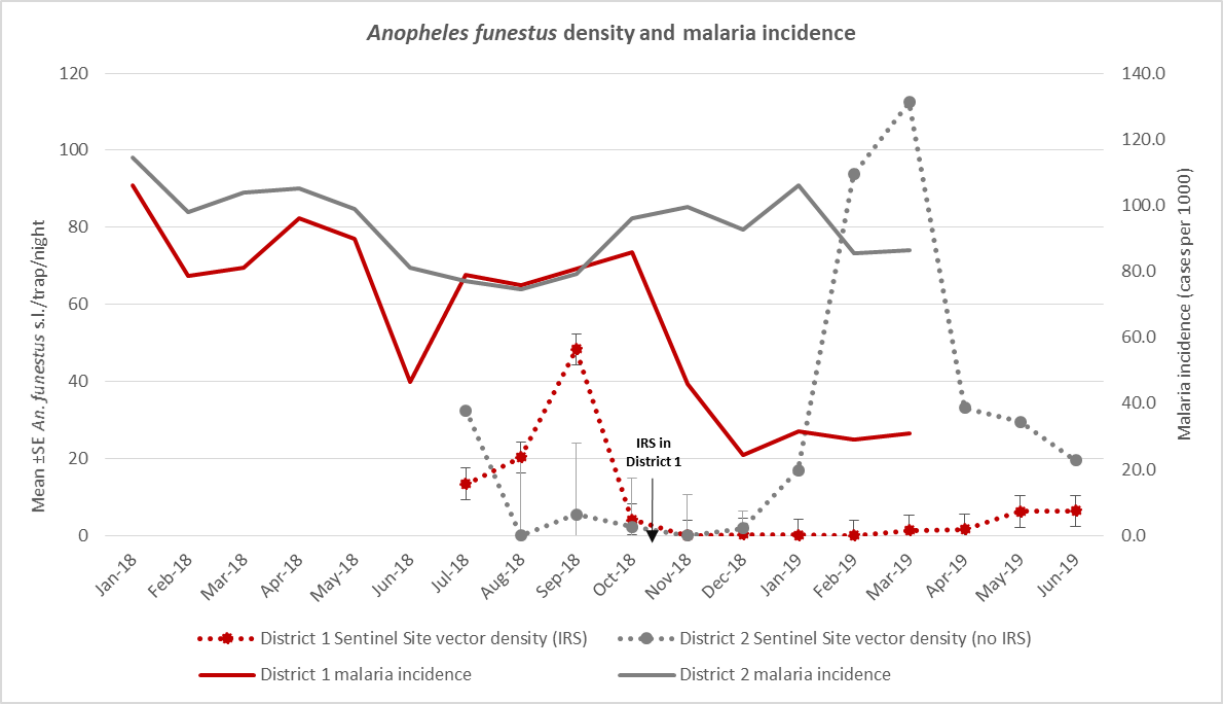
This visualization only includes data from the subset of facilities with complete data for the three years of the evaluation period. This ensures that the data is comparable across the three years. The analysis of impact should include data only from those facilities that had complete data over the study period. Incomplete reporting will mean that case incidence is underestimated. Differences in the extent to which cases are underestimated over time and between IRS and non-IRS areas will produce evaluation results that are not accurate. There is a particular risk that reporting was more incomplete in earlier versus later years of interest (e.g. 2016 versus 2018). If this is the case, but reporting rates are not taken into account in the analysis, then it may appear that cases were increasing in the absence of intervention and/or that cases did not decrease as expected with IRS due to more complete reporting over time.

In this descriptive analysis, both the areas that received IRS and those that did not had lower case incidence in 2017 than in the 2016. This could be due in part to the lower precipitation across all sites and the lower vector density observed in the IRS areas. It could also be due in part to the ITN mass campaign which covered the entire area. We also see that there seems to be an added impact of IRS, in that the areas that received IRS had lower case incidence during the peak transmission period than those that did not. When we look at 2018, there is a higher case incidence across all areas, which may be due in part to the higher precipitation and vector density than compared to 2017. In this visualization, we do not see much difference

in malaria case incidence between the IRS and non-IRS areas. This may be because the IRS campaign was held later in the year. Further statistical analysis is required to better estimate the impact of the IRS campaigns, by comparing the change before and after IRS campaigns in the health facilities that received IRS and those that did not.

Monitoring Vector Control Interventions: Quick Visualizations

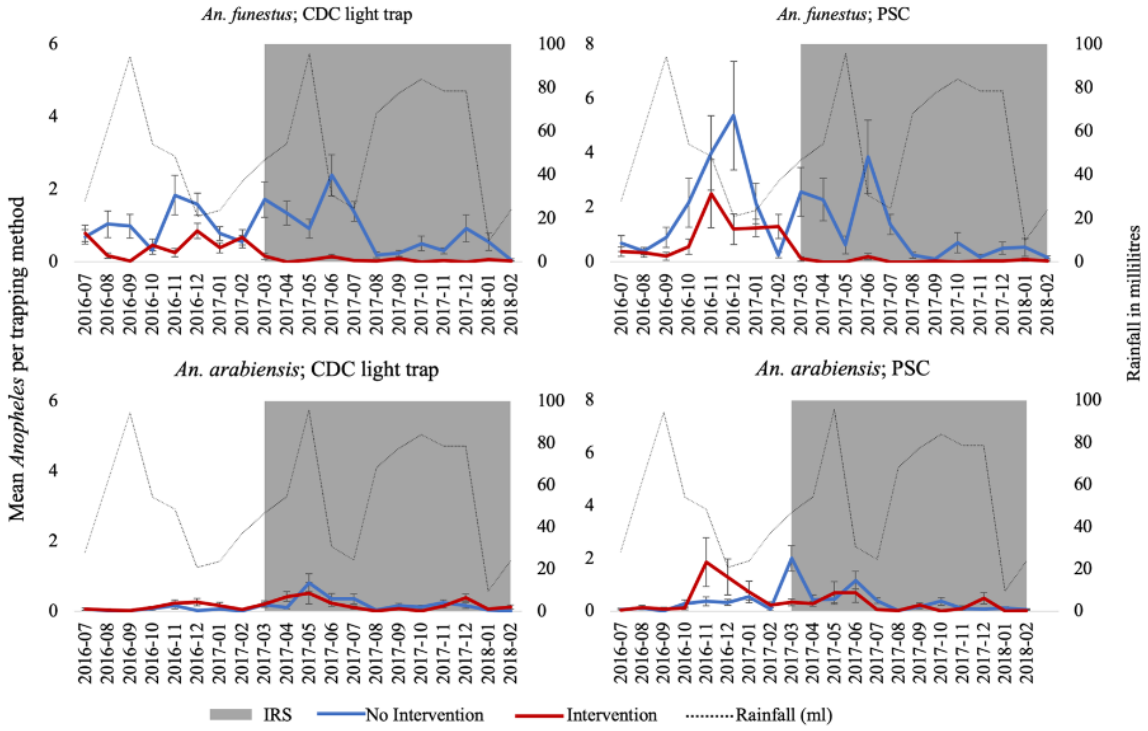
Quick Visualization 9. *Anopheles funestus* s.l. density (Indicator 1.4.1) and malaria incidence (Indicator 1.1.2), by district, site and IRS status



Software used: Excel

- In the line graph above, we can see the value of entomological data in understanding the potential effects of vector control. The dotted lines show vector density in a sentinel site that received IRS and in a sentinel site that did not receive IRS. The solid lines, which show malaria case incidence in districts that received and did not receive IRS. Overlaying the two indicators on the same visualization allows for additional interpretation of the interventions. In this combined visualization, we see that both vector density and malaria cases drop following IRS in the district that received the intervention. In the district that did not receive IRS, malaria case incidence is maintained at high levels and vector density increases over the same time period. While this type of visualization should not be assumed to infer causality from an evaluative standpoint, it is useful for understanding overall trends over time.

Quick Visualization 10. Mean *Anopheles* vector density (Indicator 1.4.1) and rainfall (Indicator 1.7.1), by IRS status, Kenya



Software used: Excel

- The graphs above show the mean number of observed female *Anopheles* mosquitoes, with the standard error, per trap-night per month in indoor CDC light trap and pyrethrum spray catch (PSC) before and after IRS in sprayed and unsprayed areas, using the primary axis (Abong'o, 2020). The secondary axis shows rainfall in milliliters. The grey shaded area indicates the months post-IRS when residual efficacy was above 80% (Indicator 1.6.2). These graphs show a reduction in *An. funestus* s.l. densities after IRS. It is more difficult to see a similar reduction in the already low densities of *An. arabiensis*. Statistical analyses were then used to determine whether there was a significant difference in the vector densities based on IRS status and collection method. The analyses found a significant reduction in the IRS sites compared to the non-IRS sites for *An. funestus* populations, through both CDC light trap and PSC methods, and *An. arabiensis* using PSC (Abong'o, 2020).

4. KEY INDICATORS

This section presents a set of key indicators that are important to inform malaria vector control decisions, along with a brief description and notes on interpretation and use. The indicators are separated into eight categories: malaria burden, IRS program coverage, ITN program coverage, vector density, insecticide susceptibility, IRS insecticide residual efficacy, and climatological indicators. The indicators were sourced from WHO, PMI and, other officially recognized sources wherever possible, and constitute a pool of standard indicators that programs can use to guide decision-making for vector control programs. Indicators are marked as: 1) established, 2) adapted, or 3) newly developed or proposed (Table 1). Annex B includes more information on these indicators, detailed descriptions, along with strengths and limitations.

Table 1. Definition of Established, Adapted and Newly Developed or Proposed Indicators

✓ **Established**	An indicator that is already well recognized and widely used in the malaria community.
Adapted	A documented indicator that was adapted from descriptions in recognized source documents to enable its use or calculation.
Newly Developed or Proposed	An indicator that was developed or proposed to meet NMCP analytical and/or visualization requests.

4.1 MALARIA BURDEN

1.1. Malaria Burden			
Purpose/Rationale: The purpose of the malaria burden indicators is to assess the burden of malaria within populations and provide a guide to the level of malaria transmission. Malaria burden indicators are also useful to determine the impact of vector control interventions.			
Indicator	**Indicator Status:**	**Description**	**Notes on Use & Interpretation**
1.1.1 Malaria Parasite Prevalence Proportion of children aged 6-59 months with malaria infection	✓ Established	**Numerator:** Number of children aged 6-59 months with malaria infection detected by rapid diagnostic test or microscopy **Denominator:** Total number of children aged 6-59 months tested for malaria parasites by rapid diagnostic test or microscopy	• Can be used to prioritize high burden areas for vector control intervention and to assess long-term changes in malaria burden; • Not ideal for assessing the impact of vector control intervention on malaria burden.
1.1.2 Malaria Case Incidence Malaria cases per 1000 population over a specific period of time	✓ Established	**Numerator:** Number of malaria cases, multiplied by 1000 **Denominator:** Total estimated population at risk of malaria	• Can be used to prioritize high burden areas for vector control intervention and to assess changes in malaria burden over short and longer term periods; • Can be used to assess the impact of vector control intervention on malaria burden

4.2 IRS PROGRAM COVERAGE

1.2. IRS Program Coverage			
Purpose/Rationale: The purpose of the IRS program coverage indicators is to assess programmatic coverage of IRS within targeted areas, as well population level coverage of IRS.			
Indicator	**Indicator Status:**	**Definition**	**Interpretation**
1.2.1 IRS Population Protected Proportion of the population protected by IRS within the targeted area, based on IRS campaign data	↻ Adapted	**Numerator:** Number of people living in structures that were sprayed during an IRS campaign. **Denominator:** Total estimated population within the targeted area	• Provides a population coverage estimate that can be used to track against national targets and compare to other vector control or malaria prevention interventions
1.2.2 Sprayed out of Found Structures (IRS Coverage) Proportion of the structures sprayed during IRS campaign out of the eligible structures found in the targeted area	✓ Established	**Numerator:** Number of eligible structures within the targeted area sprayed with a residual insecticide during IRS campaign **Denominator:** Total eligible structures found in the targeted area	• Provides a good measure of program implementation – whether the spray operators sprayed the available, known structures. WHO recommends that IRS teams spray at least 80% of houses, structures, or units within targeted areas.

Indicator	Indicator Status:	Definition	Interpretation
1.2.3 Sprayed out of Estimated Targeted Structures (IRS Progress) Proportion of the structures sprayed during IRS campaign out of the estimated targeted structures in the targeted area	✓ Established	**Numerator:** Number of eligible structures within the targeted area sprayed with a residual insecticide during IRS campaign **Denominator:** Total targeted structures in targeted area	• Can be used to assess programmatic progress of the IRS program. • May not be a measure of true coverage in a given area, as only those structures that are defined as targeted are included in the denominator.
1.2.4 Sprayed out of Total Estimated Structures Proportion of the structures sprayed during IRS campaign out of the estimated total eligible structures	Newly Developed or Proposed	**Numerator:** Number of eligible structures within the targeted area sprayed with a residual insecticide during IRS campaign **Denominator:** Total estimated eligible structures	• Can be used to assess population coverage of the IRS program; providing a structure equivalent to population coverage estimate that can be used to track against national targets.

4.3 ITN Program Coverage

1.3 ITN Program Coverage			
Purpose/Rationale: The purpose of the ITN program coverage indicators is to assess programmatic and population level coverage of ITN through distribution and ITN use.			
Indicator	**Indicator Status:**	**Definition**	**Interpretation**
1.3.1 Population ITN access Proportion of population with access to an ITN in their household	✓ Established	**Numerator:** Total number of individuals who could sleep under an ITN if each ITN in the household is used by two people **Denominator:** Total number of individuals who spent the previous night in surveyed households	• Can be used to assess population coverage of the ITN program, assuming that each ITN in a household can be used by two people in that household • Can be directly compared with ITN use to identify gaps.
1.3.2 Household ITN access Proportion of households with at least one ITN for every two people	✓ Established	**Numerator:** Number of households with at least one ITN for every two people **Denominator:** Total number of households surveyed	• Can be used to assess household coverage of the ITN program, determining the proportion of households with a sufficient number of ITNs to protect all individuals in the household, assuming two people can sleep under one ITN
1.3.3 Household ITN ownership Proportion of households with at least one ITN	✓ Established	**Numerator:** Number of households surveyed with at least one ITN **Denominator:** Total number of households surveyed	• Can be used to assess household coverage of the ITN program, determining the proportion of households with at least one ITN; Insufficient to determine universal ITN coverage according to WHO standards.
1.3.4 ITN use Proportion of the population that slept under an ITN the night before the survey	✓ Established	**Numerator:** Number of individuals who slept under an ITN the previous night **Denominator:** Total number of individuals who spent the previous night in surveyed households	• Can be used to assess ITN usage within households. Indicator that best reflects the potential protective effect of ITNs.

Indicator	Indicator Status:	Definition	Interpretation
1.3.5 ITN Use to Access Ratio Proportion of the population that slept under an ITN the night before the survey divided by Proportion of population with access to an ITN in their household	✓ Established	**Numerator:** ITN Use: Proportion of the population that slept under an ITN the night before the survey **Denominator:** ITN Access: Proportion of population with access to an ITN in their household	• Can be used to assess the behavioral gap for net use rather than a gap because not enough ITNs are available. This analysis is useful for informing ITN programs whether they need to focus on achieving higher ITN coverage, promoting ITN use or both. The closer the ratio is to 1 or 100%, the smaller the behavioral gap in net use (i.e. the fewer people in the population with access to an ITN but not using it).
1.3.6 Mass campaign ITN distribution coverage Proportion of the population protected by ITNs, based on mass ITN distribution	↻ Adapted	**Numerator:** Number of ITNs distributed in past 3 years through mass campaigns, multiplied by 2 **Denominator:** Total estimated population	• Can be used to assess whether enough ITNs were distributed during a mass campaign to cover the population with 1 net for every 2 persons and can highlight gaps in the distribution.
1.3.7 ANC ITN distribution coverage Proportion of pregnant women attending first antenatal care (ANC1) visit who received an ITN during their ANC visit	↻ Adapted	**Numerator:** Number of pregnant women who received an ITN during their first ANC visit **Denominator:** Total pregnant women attending first ANC visit	• Can be used to assess whether women who attended their first ANC visit received an ITN. Without additional information, such as ITN stock data, it cannot detail why the women did not receive an ITN.
1.3.8 EPI ITN distribution coverage Proportion of infants 0-11 months attending the expanded program on immunization (EPI) who received an ITN during their EPI visit	↻ Adapted	**Numerator:** Number of infants 0-11 months attending EPI who received an ITN during their EPI visit **Denominator:** Total infants 0-11 months attending EPI visit	• Can be used to assess whether infants who attended their EPI visit received an ITN. Without additional information, such as ITN stock data, it cannot detail why infants did not receive an ITN.
1.3.9 ANC and EPI ITN population distribution coverage Proportion of estimated pregnant women and infants 0-11 months who received an ITN during their ANC or EPI visit	↻ Adapted	**Numerator:** Number of pregnant women and infants 0-11 months who received an ITN during their ANC or EPI visit **Denominator:** Total estimated pregnant women and infants 0-11 months based on population projections	• Can be used to assess vulnerable population ITN distribution coverage against national targets and to compare population based coverage with other vector control interventions. Reviewed with ANC/EPI ITN distribution, this population-based estimate can help to determine whether individuals not receiving ITNs is due primarily to non-attendance at health facilities or not receiving ITNs when they do attend.
1.3.10 ITN Population distribution coverage through all channels Proportion of population at risk potentially covered by ITNs distributed	↻ Adapted	**Numerator:** Number of ITNs distributed in past 3 years through all channels, including mass campaigns, ANC/EPI, school-based distribution and community-based campaigns, multiplied by 2 **Denominator:** Total estimated population at risk of malaria	• Can be used to assess total population ITN distribution coverage against national targets and to compare population based coverage with other vector control interventions. • Since it totals the number of ITNs distributed over the past three years, is likely an overestimate of the true population protected. Over time, ITNs are lost, torn or no longer used.

4.4 VECTOR DENSITY

1.4 Vector Density			
Purpose/Rationale: The purpose of the vector density indicator is to determine the seasonality of transmission, the optimal timing of interventions based on transmission season(s), and the impact of vector control interventions.			
Indicator	**Indicator Status:**	**Definition**	**Interpretation**
1.4.1 Vector density Number of adult female *Anopheles* malaria vectors, disaggregated by species, collected per sample collection - collections and unit time	✓ Established	**Numerator:** Number of adult female *Anopheles* malaria vectors collected, disaggregated by species **Denominator:** Number of sample collections	• Can be used to assess the impact of vector control interventions on reducing vector populations. It is typically an indicator that can be estimated in most endemic settings. While other key indicators, such as sporozoite rate and entomological inoculation rate (EIR) are more closely related to malaria transmission, they may require large sample sizes that may not be feasible to collect in some settings. In addition, these measures may not show enough variation to assess the impact of vector control interventions. • Should always be disaggregated by method of collection and collection location (i.e. indoors and outdoors).

4.5 INSECTICIDE SUSCEPTIBILITY

1.5 Insecticide Susceptibility			
Purpose/Rationale: The purpose of the insecticide susceptibility indicators is to guide selection of tools or products that are effective against the wild vector populations.			
Indicator	**Indicator Status:**	**Definition**	**Interpretation**
1.5.1 Insecticide susceptibility Proportion of adult female *Anopheles* malaria vectors dead after exposure to a discriminating concentration of insecticide ± synergist[1] [1]With adjustment by Abbot's formula (see Annex B 1.5.1)	✓ Established	**Numerator:** Number of dead or incapacitated (i.e. unable to fly) adult female *Anopheles* malaria vectors **Denominator:** Total number of adult female *Anopheles* malaria vectors exposed to a discriminating concentration of insecticide in standard bioassays or insecticide plus synergist assay	• Can be used to support the selection of insecticides for IRS and ITNs. • At least 100 mosquitoes per species should be exposed in a given sample. In lower transmission areas, it may be difficult to obtain adequate samples of mosquitoes for susceptibility testing. Results from smaller samples can be difficult to interpret. • Insecticide susceptibility should be collected on the same vectors that rest and/or bite indoors, as these are the vectors being targeted by IRS or ITNs.
1.5.2 Insecticide susceptibility intensity Proportion of adult female *Anopheles* malaria vectors dead after exposure to 5x or 10x discriminating concentrations of an insecticide	✓ Established	**Numerator:** Number of dead or incapacitated adult female *Anopheles* malaria vectors **Denominator:** Total number of adult female *Anopheles* malaria vectors exposed to 5x or 10x discriminating concentration of insecticide in standard bioassays	• Can be used to support the selection of insecticides for IRS and ITNs. This indicator is intended to measure the strength of expressions of resistance phenotypes to help assess the operational significance of the resistance where detected. • At least 100 mosquitoes per species should be exposed in a given sample. In lower transmission areas, it may be difficult to obtain adequate samples of mosquitoes for susceptibility testing. Results from smaller samples can be difficult to interpret.

4.6 IRS Insecticide Residual Efficacy

1.6 IRS Insecticide Residual Efficacy			
Purpose/Rationale: The purpose of the IRS insecticide residual efficacy is to determine the period of time the IRS insecticide remains effective against malaria vectors.			
Indicator	**Indicator Status:**	**Definition**	**Interpretation**
1.6.1 IRS insecticide residual efficacy Percent of adult female *Anopheles* malaria vectors who died after exposure to insecticide-treated surface in the field, by active ingredient, site, and wall type	✓ Established	**Numerator:** Number of adult female *Anopheles* malaria vectors who died after exposure to insecticide-treated surface in field, by active ingredient, site, and wall type **Denominator:** Total number of adult female *Anopheles* malaria vectors exposed to insecticide-treated surface in the field, by active ingredient, site, and wall type	• Can be used to estimate the time period that the IRS product remains effective against the vectors. The WHO standard is to have above 80% mosquito mortality for the product to be considered effective. Samples are tested one week after spraying, and then every month until mosquito mortality drops below 80% for 2 consecutive months.[1] • Can be used to help interpret the impact of IRS on malaria case incidence. However, residual efficacy results can vary widely across settings, years, and sprayable surfaces, sometimes making results difficult to interpret.
1.6.2 IRS insecticide residual efficacy months Average number of months for which IRS insecticide residual efficacy remains above 80% across site and wall type	✓ Established	Average number of months for which IRS insecticide residual efficacy remains above 80% across site and wall type	• Can be used to estimate the time period that the IRS product remains effective against the vectors. This indicator uses the continuous IRS insecticide residual efficacy indicator and creates a binary indicator for each month, where the value is above or below the 80%. This makes it easier to interpret and compare across insecticides but may hide variation. • Can be used to help inform IRS spray timing and frequency by identifying the point in time when IRS efficacy does not extend through the malaria transmission season.

[1] World Health Organization. 2006. *Guidelines for testing mosquito adulticides for indoor residual spraying and treatment of mosquito nets.* Geneva: World Health Organization; https://apps.who.int/iris/bitstream/handle/10665/69296/WHO_CDS_NTD_WHOPES_GCDPP_2006.3_eng.pdf

4.7 CLIMATOLOGICAL INDICATORS

1.7 Climatological Indicators			
Purpose/Rationale: The purpose of the climatological indicators is to better understand the vector control intervention context, and climate factors that may independently affect the malaria burden from year to year.			
Indicator	**Indicator Status:**	**Definition**	**Interpretation**
1.7.1 Mean precipitation Average precipitation within a given area over a period of time	 **Newly Developed or Proposed**	Average precipitation within a given area over a period of time	• Can be used to explain increases or decrease in vector density and malaria case incidence form year to year. • Precipitation data is available as a spatial file. In order to effectively use precipitation data valid administrative boundaries must be available to match to the precipitation data. This makes it difficult to use at lower levels, such as the health facility catchment level, where documented administrative boundaries are not available.
1.7.2 Mean enhanced vegetation index Average vegetation greenness within a given area over a period of time	 **Newly Developed or Proposed**	Average vegetation greenness within a given area over a period of time	• In combination with other indicators, this can help to explain increases or decrease in vector density and malaria case incidence from year to year and between geographical areas. • It can be a useful complement to precipitation as it can indicate whether precipitation is absorbed within an area creating an environment suitable for mosquitoes. • The enhanced vegetation index data is available as a spatial file. As with precipitation, in order to effectively use precipitation data valid administrative boundaries must be available to match to the precipitation data. This makes it difficult to use at lower levels, such as the health facility catchment level, where documented administrative boundaries are not available.

5. TIPS & RESOURCES

In this section, we present some practical recommendations for how stakeholders can achieve this integrated approach to analysis and visualization, including how to:

- Engage stakeholders in integrated data analysis and data visualization design and use
- Manage vector control data
- Integrate datasets from multiple sources, and
- Proactively plan for improved data use for malaria control decisions.

5.1 ENGAGING DECISION-MAKERS IN THE DESIGN PROCESS

- **Engage decision-makers early and often**, using user-centered design principles to ensure the decision-support products (analyses and visualizations) meet stakeholder needs.
- **Ask** national program colleagues and partners involved in vector control decision-making to help review the current decision-making processes, gaps, and user needs. Figure 2 provides an example question guide that can be used or adapted to support this stakeholder engagement process. Focus on:
  - Listing the most critical vector control decisions that need to be made, and the processes and timing of those decisions,
  - Reviewing the current decision-making processes, pain points in this process, and how stakeholders would like this process to be different; and,
  - Identifying the guidance, data and other resources that currently exist to inform malaria vector control decision-making.
- **Document and formalize decision-making processes** based on interview findings, if they are not already documented.
- **Mock-up the visualization designs using paper and pencil**, or computer-based drawing programs before working in visualization software. This facilitates quick sharing and feedback gathering among key stakeholders, before working with actual data analysis and visualization tools.

Tips for Engaging Decision-Makers in the Design Process

Data Tools & Systems
- N/A

Staffing Considerations:
- Data Analyst/Visualization Specialist with visualization development experience, background in user-centered design and visualization design principles
- Program Leadership with commitment to using data for decision-making

Additional Resources:
- Entomological Surveillance Planning Tool
- Facilitating Surveillance, Monitoring, and Evaluation in Malaria-Endemic Countries: A Compendium for National Malaria Programs. Chapters 4: The Role of Data in Decision-Making; Chapter 12: Data Presentation, Interpretation, & Use

Figure 2. Vector Control Decision-Making Interview Guide

Step 1: Identify the decisions, timeline, and decision-makers

1. What types of decisions must be made for effective malaria vector control? For IRS, ITNs, other?
    - Some examples may include location, product choice, timing, stratification/targeting?
2. What questions do you need to respond for vector control decision-making as part of your work?
3. When are these decisions about vector control made?
4. What are meetings/venues for making these decisions?
5. Who are the stakeholders and what are their roles in these decision-making processes?
    - Who decides? Who influences decisions?
    - Which level are these decisions made at? (national, provincial, district)

Step 2: Describe current decision-making processes

6. What data or resources do decision makers currently use to guide these decisions?
    - Probe for specific guidance documents, reports, indicators. Obtain examples.
7. Can you describe the decision-making process to me step-by-step? What information do decision-makers look at/consider first, second, third……?
8. Of the resources that we have discussed, which ones are the most useful to guide decisions and why? Can you provide examples of these sources, including reports or visualizations?
9. What are the greatest challenges in reviewing evidence to guide vector control decision-making?
10. What suggestions do you have for improving the way vector control decisions are made?
    - What if any additional information or resources would improve the processes for making the decisions that you have described?

Step 3: Describe the future decision-making products

11. What questions do you wish you could answer but that you currently cannot? If you answer these questions, what impact will it have?
12. Is there any evidence that you wish you had access to in order to guide decision-making? Please describe.
13. Do you have data now to answer this question? Do you think the data could be made available?
14. Do you have any sketches / models / drawings of visualizations you would like to see?
15. How often would you like to update the visualizations?
16. How would you like these decision-making products or visualizations be shared? (online interactive dashboard, PPT, reports, others?)

5.2 MANAGING DATA

- **Ensure data is collected for the key indicators that will help answer critical vector control questions, at the necessary level of detail:** A foundational element of any strong national malaria surveillance, monitoring and evaluation (SME) plan is a clear articulation of the **key indicators** required to support decisions. The selection of key indicators may be supported by the stakeholder engagement process recommended above. If any of the identified priority indicators are not already part of a broader SME or other strategic plan, it will be important for stakeholders to identify how to incorporate them. Whenever possible, standardized data collection tools and forms should be used to ensure consistency of data collection across dimensions (for instance, across locations, over time, and among partners). Given the heterogeneity of malaria, and the increasing need for more localized decision-making, stakeholders should also consider whether data on key indicators is being collected at the level of detail required for decision-making, considering factors such as geographic level (national, regional, district levels), vector control product, or vector species. Increasing granularity of the data can be more costly, but can result in more accurate, evidence-based decision-making based on local conditions.
- **Ensure strong data management practices are developed and supported:** Once key malaria indicators are selected and prioritized, stakeholders must ensure that robust **data management** tools and processes are in place and supported. An effective and efficient data life cycle is supported by the development and use of standardized data collection tools, as noted above, and the use of reliable **databases** or **data management systems**.
- **Where possible, manage and store vector control datasets in the same database**: The incorporation of vector control and entomological data into structured databases, and ideally into the same integrated data systems already in use for other routine malaria data, will facilitate integrated analytics efforts[2]. For example, in Mali, the government had malaria case data and ITN data within the same DHIS2 instance.

Tips for Managing Data

Data Tools & Systems

- Structured database software

Staffing Considerations:

- Data entry staff with experience in timely, accurate data entry
- Data entry supervisors with experience developing and implementing data quality protocols
- Database manager(s), with relevant database experience, who maintains and updates system metadata, ensuring alignment of key characteristics that facilitate integration of datasets

Additional Resources:

- Facilitating Surveillance, Monitoring, and Evaluation in Malaria-Endemic Countries: A Compendium for National Malaria Programs
- Entomological Surveillance Planning Tool
- WHO Global Malaria Program, DHIS2 DHIS2-based entomology and vector control data collection and collation tools

[2] The WHO Global Malaria Program is developing a comprehensive set of DHIS2-based malaria vector control and entomological data standard data modules that country programs may adopt to incorporate these important data sets into existing HMIS. A link to additional information is provided in the Additional Resources box above.

5.3 Reviewing Data and Assessing Quality

- **Access required datasets:** Guided by the stakeholder engagement interviews, identify the required datasets and essential variables. If there is no single managed database, develop a simple Excel-based template to share with partners to clarify the specific variables and preferred data format. Request the data from the owners.
- **Understand each dataset and its level of detail:** Review the data, making sure it's what you expect and that it has the right level of detail. The level of detail is "What makes each row in the dataset unique?" It usually includes a geographic hierarchy (district, health facility or entomological site), time period (day, month, year), and may also involve other variables, such as age group, intervention type or product used.
- **Review individual datasets for data quality.** Check the data received for completeness (what proportion of the expected data is missing?), internal consistency (i.e., is there any period where the number of structures sprayed is greater than the structures found?), and outliers (values outside of the expected range).
- **Document key findings from the data quality review**: After conducting the data quality review, prepare a series of data quality visualizations or a short report summarizing key indicators, how the findings may affect decision-making, and specific questions for stakeholders to elicit their preferences on how/whether data should be used based on the review.
- **Share data quality review findings with stakeholders.** During a data quality review meeting present the results to key stakeholders and pose the questions required to inform the vector control decision-making visualizations. Work with stakeholders to reach a consensus on how they would like to use the data and what constitutes "good enough" quality of data for their decision-making process. Use this as an opportunity to prioritize data quality improvements based on decision-makers' needs.
- **Plan how data quality measures will be incorporated into visualizations.** Data quality can be incorporated into the final visualization product by a) including a separate set of visualizations that explore data quality, b) including indicators of data quality directly within the main visualizations, c) providing an introduction that notes data cleaning modifications already built into key indicators, or d) developing visualizations that allow users to dynamically choose the level of data quality they are willing to accept.

Tips for Reviewing Data & Assessing Quality

Data Tools/Systems

- Basic: Excel, Access, DHIS2
- Advanced: R, Python, PowerBI, PowerQuery, Stata, SAS, Tableau Prep, Alteryx

Staffing Considerations:

- Data managers or analysts who have familiarity with the datasets of interest and experience with managing and cleaning datasets; who are also in close contact with data collectors and have time availability to provide feedback

Additional Resources:

- Facilitating Surveillance, Monitoring, and Evaluation in Malaria-Endemic Countries: A Compendium for National Malaria Programs. Chapter 11: Data Quality, Data Management and Analysis
- A Practical Guide to Using Routine Data in Evaluation

5.4 INTEGRATING DATASETS

- **Access, process & clean data:**
  - Are all the required datasets available? Are all required variables included within the datasets?
  - Is there a data dictionary or have stakeholders been consulted to understand how to interpret and use the variables included?
  - Are the datasets clean with no missing data, no duplicate entries and no values outside of the expected ranges?
  - Are the data files formatted in a machine-readable, tidy format with one row of headers, each variable forms a column, and each observation forms a row?
- **Join with standardized geographical area list:**
  - Is there a geographical area hierarchy available (i.e. region, district, health facility or entomological site, geocoordinates)?
  - Can each dataset be matched to others based on their geographical area, or does a crosswalk need to be manually developed to match datasets?
  - Do stakeholders need to be consulted to clarify or validate matching geographical area?
- **Transform to match the desired end product:**
  - Has a list of all variables that need to be calculated in the final integrated dataset been developed?
  - In each individual dataset, have variables been renamed and transformed to include standardized variables to match across datasets?
  - Has the data been transformed to match the required level of detail (i.e. health facility-month, household night) of the final integrated dataset?
- **Combine datasets of the same type:**
  - Have the datasets of the same type (i.e. multiple IRS datasets from multiple years or partners) been combined?
  - Has the final file been checked for any missing or duplicate data, after being combined?
- **Combine datasets of different types:**
  - Have the datasets of the different type (i.e. IRS, ITN, entomological, malaria case, and/or population datasets) been combined?
  - Has the final file been checked for any missing or duplicate data, after being combined?
  - Have all necessary cross-dataset indicators been calculated (i.e. population protected by ITNs from the ITN data and estimated population, often available from the central statistics office? Are any values outside of the expected range?
- **Develop visualizations:**
  - Have stakeholders been consulted in the design of the visualizations? Were visualization mock-ups designed and shared with stakeholders for feedback prior to development?
  - Do the visualizations incorporate all key data required for decision-making, and are they presented in order according to the decision-making process?

Tips for Integrating Datasets

Data Tools/Systems

- Basic: Excel, Access, DHIS2
- Advanced: R, Python, PowerBI, PowerQuery, Stata, SAS, Tableau Prep, Alteryx, QGIS, ArcGIS

Staffing Considerations:

- Data Analyst who has experience with advanced data preparation and analysis software and the integration of large, complex datasets; For use of climate datasets, skills in geospatial analysis are also useful.

Additional Resources:

- Facilitating Surveillance, Monitoring, and Evaluation in Malaria-Endemic Countries: A Compendium for National Malaria Programs. Chapter 11: Data Quality, Data Management and Analysis
- A Practical Guide to Using Routine Data in Evaluation

5.5 Enhancing Data Use

- **Engage decision-makers in design:** Engaging the end users in the design of visualizations, and designing products to meet their needs, increases the likelihood of data use.
- **Develop products that are timely, digestible and action-oriented:**
  - Timely: available in time for key decision-points. The timing of key decision-points can be mapped out as part of the initial decision-maker interviews, data collection, processing and analysis plans can be developed to meet those timelines.
  - Digestible: presented in a format that is easy to read and interpret. Visualizations should include only the necessary data elements required to answer the question of interest. All other information that is not immediately relevant should not be included.
  - Action-oriented: presented in format that elevates a clear sense of the decisions to be made and actions to take. Visualizations developers should think of the data as a story. Using information from the decision-maker interviews, the visualizations should walk users step-by-step through to the decision-making process.
- **Support data use through data review meetings.** Visualizations are often more effective when they are integrated within established data review and decision-making processes (PATH, 2019). Well-structured data review meetings facilitate the review and interpretation of data, employ a structured, team-oriented approach to problem-solving, and draw from continuous quality improvement methodologies. Visualizations to inform vector control decisions can be shared during vector control steering committee meetings, routine data review meetings, or through special or ad hoc meetings or workshops. Data review meetings should be used as an opportunity to review the developed visualizations, to provide feedback on data quality issues, and to refine the documentation of the decision-making criteria and process based on real-life decision-making experience. Each data review meeting should end with an action plan with clearly define roles and responsible parties and deadlines for implementation.

Tips for Enhancing Data Use

Data Tools/Systems

- Basic: DHIS2, Excel
- Advanced: Tableau, PowerBI, R, R Shiny

Staffing Considerations:

- Data Analyst/Visualization Specialist with visualization development experience, background in user-centered design and visualization design principles
- Program Leadership with commitment to using data for decision-making

Additional Resources:

- Facilitating Surveillance, Monitoring, and Evaluation in Malaria-Endemic Countries: A Compendium for National Malaria Programs. Chapters 4: The Role of Data in Decision-Making; Chapter 12: Data Presentation, Interpretation, & Use
- A Guide for Conducting Malaria Data Review Meetings
- Monitoring and evaluation of malaria-related routine data during the COVID-19 pandemic
- Analysis and use of Health Facility Data: Guidance for Malaria Programme Managers
- Immunization Data: Evidence for Action. A Realist Review of What Works to Improve Data Use for Immunization, Evidence from Low- and Middle-Income Countries

ANNEX A: BIBLIOGRAPHY

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ANNEX B: DETAILED INDICATOR DESCRIPTIONS

1.1 MALARIA BURDEN

Purpose/Rationale: The purpose of the malaria burden indicators is to assess the burden of malaria within populations and provide a guide to the level of malaria transmission. Malaria burden indicators are also useful to determine the impact of vector control interventions.

1.1.1 MALARIA PARASITE PREVALENCE

Indicator: Malaria parasite prevalence (Proportion of children aged 6-59 months with malaria infection)

> **Numerator:** Number of children aged 6-59 months with malaria infection detected by rapid diagnostic test or microscopy
>
> **Denominator:** Total number of children aged 6-59 months tested for malaria parasites by rapid diagnostic test or microscopy

✓ **Established** Indicator Source: Roll Back Malaria Monitoring and Evaluation Reference Group Survey and Indicator Task Force (2018). Household Survey Indicators for Malaria Control. Pgs. 30-34.

Data Source: Malaria parasite prevalence is obtained through household surveys. It is usually available through nationally representative household surveys, such as Demographic and Health Surveys (DHS) or Malaria Indicator Surveys (MIS). DHS and MIS data is available at: https://dhsprogram.com/Data/. It can also be collected as part of special evaluation studies.

Considerations & Interpretations:

- "Parasite prevalence can fluctuate dramatically throughout the course of a year with the seasonality of malaria, and thus values of the indicator may be influenced by the timing of a survey in relation to peak transmission. Accordingly, parasite prevalence should not be used for tracking the short-term impact of scaling up prevention efforts, because the prevalence rates may merely reflect differences in the timing of surveys in relation to within-year variation in parasite prevalence. Parasite prevalence is better suited to measuring changes in malaria burden over a longer term during which changes in parasite prevalence are expected to be much greater and outweigh within-year variation. To demonstrate a reliable trend, no more than four data points within a 10-year span are generally needed."[3]

[3] Roll Back Malaria Monitoring and Evaluation Reference Group Survey and Indicator Task Force (2018). *Household Survey Indicators for Malaria Control.* https://www.malariasurveys.org/documents/Household%20Survey% 20Indicators%20for%20Malaria% 20Control_FINAL.pdf

- In addition, given that nationally representative surveys are powered to present results at the regional level, parasite prevalence is often not suitable for evaluating interventions conducted at the sub-regional level.

Table 1.1.1. Strengths and Limitations

Strengths	• Indicator is representative of the national and regional population. • Comparable across countries if appropriate and consistent sampling procedures are followed.
Limitations	• Usually collected only every three to five years, as part of large nationally representative surveys. • Nationally representative surveys are powered to present results at the provincial or regional level and cannot provide accurate estimates for lower levels (i.e. district, county, health facility). • The survey recall period may not coincide with the intervention period, leading to an underestimate of impact.[4] • "Prevalence estimates for … malaria parasite prevalence may be biased by the seasonality of survey data collection, because survey fieldwork for DHS and MIS is sometimes done during the dry season when prevalence is likely at its lowest and fieldwork for MIS is designed to be done during the high transmission season when net use may be higher."[5]

[4] Roll Back Malaria Monitoring and Evaluation Reference Group Survey and Indicator Task Force (2018). Household Survey Indicators for Malaria Control. https://www.malariasurveys.org/documents/Household%20Survey%20Indicators%20for%20Malaria%20Control_FINAL.pdf

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1.1.2 Malaria Case Incidence

Indicator: Malaria case incidence (malaria cases per 1000 population over a specific period of time)

Numerator: Number of malaria cases, multiplied by 1000

Denominator: Total estimated population at risk of malaria

✓ **Established** Indicator Source: Adapted from: World Health Organization (2018). Malaria surveillance, monitoring & evaluation: a reference manual. Geneva: World Health Organization. Pg. 192.

Data Sources: The number of malaria cases can be obtained from national health information systems, such as the District Health Information Software 2 (DHIS2) available in many countries. Population estimates may either be available in DHIS2 or through national statistical sources such as projected census reports, or from household enumerations for specific interventions, or through geospatial sources, such as WorldPop or Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) (WorldPop, 2021; Wardrop, 2018). Whenever possible, data sources should be triangulated to guide the selection process. When values differ between sources, consultation with stakeholders is recommended to review key underlying data and assumptions (base year, annual growth rates and other adjustments), correct any errors, identify the most appropriate population data source or sources. In some cases, it may be preferable to prepare population coverage estimates using more than one data source, thus generating an estimated range of population coverage, to generate confidence in the population protected estimates.

Considerations & Interpretations:

- Inclusion or exclusion of unconfirmed cases: WHO defines malaria case incidence as confirmed cases. It is preferable to only include malaria cases confirmed by a diagnostic test, either a malaria rapid diagnostic test (RDT) or malaria microscopy. However, there may be cases where the disaggregation of malaria cases by confirmatory status (confirmed or presumed) is not available or where testing rates are very low. In these cases, it may be useful to consider all reported malaria cases, rather than only the confirmed cases.
- Malaria case incidence as a reflection of true incidence: Malaria case incidence rates may not reflect the true incidence of malaria in a population because:
    - case data are typically exclusively or primarily from the public health sector and do not include people diagnosed and treated by the private sector or those who were not diagnosed via a diagnostic test;
    - key indicators may differ by area and over time, such as:
        - the proportion of patients with suspected malaria patients who attend public health facilities and
        - the proportion of patients attending public health facilities who receive a diagnostic test; and
    - health facility reporting rates may also differ by area and over time
- "When areas with better access to health facilities report higher malaria case incidence than areas with limited access, it is useful to assess overall health facility usage, percentage of people who receive a

diagnostic test, and completeness of health facility reporting in interpreting the data. It may also be useful to examine other indicators, such as rates of diagnostic test positivity."[6]

- Population estimates for the denominator are often projections from a census. Due to population growth and human migration, whether permanent or seasonal, population estimates may not truly reflect the population within a given area. Discussion with local stakeholders can help to determine the most trusted source for population estimates.
- Malaria case incidence is usually presented by year. When assessing trends over time it is useful to use the transmission year, rather than the calendar year. The transmission year is defined by observed trends in case incidence and begins when cases first start to increase. The transmission year is preferable to a calendar year because the impact of a vector control intervention such as IRS that targets a season may have an impact that spans two calendar years.
- Within many national health information systems zeroes are not stored to save data storage space. This can make it difficult to determine health facility-months when there were truly no malaria cases from health facility-months with missing data, particularly in low burden areas. This can lead to either exclusion of low burden facilities, if nulls are excluded, or an underestimate case incidence, if the nulls are included.

Table 1.1.2. Strengths and Limitations

Strengths	• Usually collected per month and at the health facility level. In some countries available at the weekly and community level.
Limitations	• Biased by focus on public sector reporting, proportion seeking treatment at public health facilities, diagnostic testing rates and health facility reporting rates. • Limited by the accuracy of the population estimates.

[6] World Health Organization. 2018. Malaria surveillance, monitoring & evaluation: a reference manual. Geneva: World Health Organization. Licence: CC BY-NC-SA 3.0 IGO. https://www.who.int/malaria/publications/atoz/9789241565578/en/

1.2 IRS PROGRAM COVERAGE

Purpose/Rationale: The purpose of the IRS program coverage indicators is to assess programmatic coverage of IRS within targeted areas, as well population level coverage of IRS.

1.2.1 IRS POPULATION PROTECTED

Indicator: IRS population protected (Proportion of the population protected by IRS)

Numerator: Number of people living in structures that were sprayed during an IRS campaign.

Denominator: Total estimated population within the targeted area

Indicator Source: Adapted from: World Health Organization. 2015. Indoor residual spraying: An operational manual for IRS for malaria transmission, control and elimination. Pg. 58.

Data Sources: The number of people living in structures that were sprayed during an IRS campaign can usually be collected from the IRS implementing agency, whether government or an implementing partner. Population estimates may either be available in DHIS2 or through national statistical sources such as projected census reports, from household enumerations for specific interventions, or through geospatial sources, such as WorldPop or Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) (WorldPop, 2021; Wardrop, 2018). Whenever possible, data sources should be triangulated to guide the selection process. When values differ between sources, consultation with stakeholders is recommended to review key underlying data and assumptions (base year, annual growth rates and other adjustments), correct any errors, identify the most appropriate population data source or sources. In some cases, it may be preferable to prepare population coverage estimates using more than one data source, thus generating an estimated range of population coverage, to generate confidence in the population protected estimates.

Considerations & Interpretations:

- Per the WHO Indoor Residual Spraying Operational Manual (2015), one of the main outputs of IRS is number of people protected through structures or houses sprayed, with the objective of an IRS spray round is to achieve a minimum of 80% coverage of targeted population at risk.
- Interpreting coverage based on population estimates: Population estimates are often projections from census. Due to population growth and human migration, whether permanent or seasonal, population estimates may not truly reflect the population within a given area during the time of the IRS campaign. The variations can become more pronounced when assessing IRS population protected at the more granular levels of health facility catchment area or community.
- This indicator should be present with a description of any contextual details that inform its interpretation, including:
  - if selected sub-areas within an IRS targeted area were excluded for operational reasons, due to being in very remote or urban areas, or part of a wetland not eligible for spray due to environmental conditions, this should be clearly noted.
  - if there are known or suspected population movements, such as migration due to civil unrest or population influx due to economic opportunities (i.e. opening of a mine).

Table 1.2.1. Strengths and Limitations

Strengths	• Provides a population coverage estimate that can be used to track against national targets and compare to other vector control or malaria prevention interventions.
Limitations	• Limited by the accuracy of the population estimates.

1.2.2 IRS Coverage: Sprayed out of Eligible, Found Structures

Indicator: IRS coverage (Proportion of the structures sprayed during IRS campaign out of the eligible structures found in the targeted area)

Numerator: Number of eligible structures within the targeted area sprayed with a residual insecticide during IRS campaign, as reported by spray operators

Denominator: Total eligible structures found in the targeted area, as reported by spray operators

✓ Established **Indicator Source:** PMI VectorLink Monitoring and Evaluation Plan

Data Sources: Both the number of structures sprayed and the eligible structures found can usually be collected from the IRS implementing agency, whether government or an implementing partner.

Considerations & Interpretations:

- When at least 80% of structures in a community receive IRS it provides community protection against malaria infection.[7]
- IRS coverage is a good measure of program effort but may not adequately assess true coverage of the IRS intervention. Depending on the terrain of the area, there may be structures that the spray operator does not find because they are in pockets of isolated structures.
- Including reasons why some eligible, found, structures were not sprayed as sub-indicators can help programs determine the key barriers to IRS uptake, such as household refusal or structures locked due to absence for seasonal work.

Table 1.2.2. Strengths and Limitations

Strengths	• Provides a good measure of program implementation – whether the available, known structures were sprayed by the spray operators. WHO recommends that IRS teams spray at least 80% of houses, structures, or units within targeted areas.[8]
Limitations	• It is not a measure of true coverage in a given area, as only those that are found by spray operators are included in the denominator.

[7] Rehman AM, Coleman M, Schwabe C, et al. How much does malaria vector control quality matter: the epidemiological impact of holed nets and inadequate indoor residual spraying. PLoS One. 2011;6(4):e19205. Published 2011 Apr 29. doi:10.1371/journal.pone.0019205

[8] World Health Organization. 2015. Indoor residual spraying: An operational manual for IRS for malaria transmission, control and elimination. https://www.who.int/malaria/publications/atoz/9789241508940/en/

1.2.3 IRS Progress: Sprayed out of Targeted Structures

Indicator: IRS progress (Proportion of the structures sprayed during IRS campaign out of the estimated targeted structures in the targeted area)

Numerator: Number of eligible structures within the targeted area sprayed with a residual insecticide during IRS campaign, as reported by spray operators

Denominator: Total targeted structures in targeted area

✓ Established **Indicator Source:** PMI VectorLink Monitoring and Evaluation Plan

Data Sources: Both the number of structures sprayed and the targeted structures are usually available from the IRS implementing agency, whether government or an implementing partner. Governments and implementing partners may use a variety of data sources and methods to determine the number of targeted structures. This is further described under considerations below.

Considerations & Interpretations:

- Target estimates: Programs use several methods to set the targeted number of structures for the coming year including the number of found structures from the previous year, structure estimates from geospatial surveys, household enumeration, or estimates based on population. Whenever possible, data sources should be triangulated to guide the selection process. When values differ between sources, consultation with stakeholders is recommended to review key underlying data and assumptions (base year, annual growth rates and other adjustments), correct any errors, identify the most appropriate data source for targeted structures. Program staff may set the targeted number of structures as the total estimated eligible structures within an area or, due to resource constraints, targeted structures may reflect a partial number of the estimated eligible structures in an area.

Table 1.2.3. Strengths and Limitations

Strengths	• Provides an estimate of the status of program implementation – whether the number of targeted structures that the program intended to spray were sprayed.
Limitations	• IRS progress may vary based on the method used to define targeted structures. • Quality of IRS progress estimates may vary depending on the reliability of the data source for estimating targeted structures. • May not be a measure of true coverage in a given area, as only those structures that are defined as targeted are included in the denominator.

1.2.4 Sprayed out of Total Estimated Structures

Indicator: Sprayed out of total estimated structures (Proportion of the structures sprayed during IRS campaign out of the estimated total eligible structures)

Numerator: Number of eligible structures within the targeted area sprayed with a residual insecticide during IRS campaign

Denominator: Total estimated eligible structures

Newly Developed or Proposed

Indicator Source: No previously documented indicator source.

Data Sources: The number of structures sprayed are usually available from the IRS implementing agency, whether government or an implementing partner. Governments and implementing partners may use a variety of methods to determine the total estimated eligible structures. Data sources from eligible structures comes from IRS program data and population source estimates. This is further described under considerations below.

Considerations & Interpretations:

- Total eligible structures estimates: While "found structures" relies on spray operators in the field to count structures, programs use several methods to obtain a count of the total number of estimated eligible structures within an area, including the number of found or targeted structures from the previous year, structure estimates from geospatial surveys, household enumeration, or estimates based on population. The number of total structures is designed to capture all estimated eligible structures in a given area, including both the targeted and untargeted structures. Depending on the targeting strategy, the total number of estimated eligible structures may be the same as the targeted structures.

Table 1.2.4. Strengths and Limitations

Strengths	• Can provide an estimate of the total number of structures within a given area, which may be separate from the subset of targeted or found structures. • Provides a structure equivalent to population coverage estimate that can be used to track against national targets.
Limitations	• Quality of estimates may vary depending on the reliability of the data source for estimating total eligible structures.

1.3 ITN PROGRAM COVERAGE

Purpose/Rationale: The purpose of the ITN program coverage indicators is to assess programmatic and population level coverage of ITN through distribution and ITN use.

1.3.1 POPULATION ITN ACCESS

Indicator: Population ITN access (Proportion of population with access to an ITN in their household)

> **Numerator:** Total number of individuals who could sleep under an ITN if each ITN in the household is used by two people
>
> **Denominator:** Total number of individuals who spent the previous night in surveyed households

✓ **Established** Indicator Source: Roll Back Malaria Monitoring and Evaluation Reference Group Survey and Indicator Task Force (2018). Household Survey Indicators for Malaria Control. Pgs. 15-16.

Data Sources: This indicator is usually available through nationally representative household surveys, such as DHS or MIS. DHS and MIS data is available at: https://dhsprogram.com/Data/ . It can also be collected as part of special evaluation studies.

Considerations & Interpretations:

- "This indicator estimates the proportion of the population that could potentially be covered by existing ITNs, assuming that each ITN in a household can be used by two people in that household."[9]
- It has been recommended that "when programs assess the success of ITN distribution activities, population access to ITNs should be considered as the better indicator of 'universal coverage,' because it is based on people as the unit of analysis." This is because "under current ITN distribution strategies, the global malaria community cannot expect countries to reach 80% of households owning 1 ITN for 2 people at a national level."[10]

Table 1.3.1. Strengths and Limitations

Strengths	• Accounts for all ITNs in households. • Can be directly compared with ITN use to identify gaps. • Indicator is representative of the national and regional population. • Comparable across countries if appropriate and consistent sampling procedures are followed.
Limitations	• Usually collected only every three to five years, as part of large nationally representative surveys. • Nationally representative surveys are powered to present results at the provincial or regional level and cannot provide accurate estimates for lower levels (i.e. district, county, health facility). • The survey period may not coincide with the ITN distribution campaigns, causing ITN access to be underestimated.

[9] Roll Back Malaria Monitoring and Evaluation Reference Group Survey and Indicator Task Force (2018). Household Survey Indicators for Malaria Control. https://www.malariasurveys.org/documents/Household%20Survey%20Indicators%20for%20Malaria%20Control_FINAL.pdf

[10] Koenker, H., Arnold, F., Ba, F. et al. 2018. Assessing whether universal coverage with insecticide-treated nets has been achieved: is the right indicator being used?. Malar J 17, 355 (2018). Accessed 29 May 2020. Available at: https://doi.org/10.1186/s12936-018-2505-0

1.3.2 HOUSEHOLD ITN ACCESS

Indicator: Household ITN access (Proportion of households with at least one ITN for every two people)

Numerator: Number of households with at least one ITN for every two people

Denominator: Total number of households surveyed

✓ **Established**

Indicator Source: Roll Back Malaria Monitoring and Evaluation Reference Group Survey and Indicator Task Force (2018). Household Survey Indicators for Malaria Control. Pg. 14.

Data Sources: This indicator is usually available through nationally representative household surveys, such as DHS or MIS. DHS and MIS data is available at: https://dhsprogram.com/Data/ . It can also be collected as part of special evaluation studies.

Considerations & Interpretations:

- This indicator is used to determine the proportion of households with a sufficient number of ITNs to protect all individuals in the household, assuming two people can sleep under one ITN.
- If the difference between this indicator and household ITN ownership is substantial, "programs need to assess whether current ITN distribution strategies should be revised to address the gap – and ensure households have an appropriate number of ITNs."[11]
- When compared to population ITN access, this indicator underestimates coverage by ignoring households with ITNs covering some but not all individuals within the household. To further explain the difference: "This indicator produces a value of 1 or 0 for each household based on whether there is full household coverage or enough nets in the household to cover all household members. Even 90 percent coverage in a household would lead to a value of 0 for the house. Thus, this indicator often has fairly low values even in countries with high levels of ITN coverage."

Table 1.3.2. Strengths and Limitations

Strengths	• Correlates with WHO and country goals of providing 1 ITN for every 2 people. • Easy to communicate to stakeholders • Indicator is representative of the national and regional population. • Comparable across countries if appropriate and consistent sampling procedures are followed.
Limitations	• Underestimates coverage by ignoring households with ITNs covering some but not all individuals. • Usually collected only every three to five years, as part of large nationally representative surveys. • Nationally representative surveys are powered to present results at the provincial or regional level and cannot provide accurate estimates for lower levels (i.e. district, county, health facility). • The survey period may not coincide with the ITN distribution campaigns, causing their access to be underestimated.

[11] Roll Back Malaria Monitoring and Evaluation Reference Group Survey and Indicator Task Force (2018). Household Survey Indicators for Malaria Control. https://www.malariasurveys.org/documents/Household%20Survey%20Indicators%20for%20Malaria%20Control_FINAL.pdf

1.3.3 HOUSEHOLD ITN OWNERSHIP

Indicator: Household ITN ownership (Proportion of households with at least one ITN)

Numerator: Number of households surveyed with at least one ITN

Denominator: Total number of households surveyed

✓ **Established** Indicator Source: Roll Back Malaria Monitoring and Evaluation Reference Group Survey and Indicator Task Force (2018). Household Survey Indicators for Malaria Control. Pg. 13.

Data Sources: This indicator is usually available through nationally representative household surveys, such as DHS or MIS. DHS and MIS data is available at: https://dhsprogram.com/Data/ . It can also be collected as part of special evaluation studies.

Considerations & Interpretations:

- "This indicator provides a measure for household ownership of an ITN. It reflects the extent to which ITN programs have reached all households or, conversely, the proportion of households not yet reached."[12]

Table 1.3.3. Strengths and Limitations

Strengths	• Assesses minimum coverage of ITNs. • Indicator is representative of the national and regional population. • Comparable across countries if appropriate and consistent sampling procedures are followed.
Limitations	• Insufficient to determine universal ITN coverage according to WHO standards. • Usually collected only every three to five years, as part of large nationally representative surveys. • Nationally representative surveys are powered to present results at the provincial or regional level and cannot provide accurate estimates for lower levels (i.e. district, county, health facility). • The survey period may not coincide with the ITN distribution campaigns, causing ITN ownership to be underestimated.

[12] Roll Back Malaria Monitoring and Evaluation Reference Group Survey and Indicator Task Force (2018). Household Survey Indicators for Malaria Control. https://www.malariasurveys.org/documents/Household%20Survey%20Indicators%20for%20Malaria%20Control_FINAL.pdf

1.3.4 ITN USE

Indicator: ITN use (Proportion of the population that slept under an ITN the night before the survey)

Numerator: Number of individuals who slept under an ITN the previous night

Denominator: Total number of individuals who spent the previous night in surveyed households

✓ **Established** Indicator Source: Roll Back Malaria Monitoring and Evaluation Reference Group Survey and Indicator Task Force (2018). Household Survey Indicators for Malaria Control. Pg. 17.

Data Sources: This indicator is usually available through nationally representative household surveys, such as DHS or MIS. DHS and MIS data is available at: https://dhsprogram.com/Data/ . It can also be collected as part of special evaluation studies.

Considerations & Interpretations:

- "This indicator may be biased by the seasonality of survey data collection, since survey fieldwork for DHS and MIS is most often done during the dry season when net use is likely at its lowest." [13]
- "This indicator provides a direct measure of ITN use by all age groups at the time of the survey. It includes all individuals who spent the previous night in surveyed households, including visitors, regardless of whether those individuals had access to an ITN in their own households." It can be broken down by five-year age brackets, gender, pregnancy status and other demographic variables for programmatic analysis.

Table 1.3.4. Strengths and Limitations

Strengths	• Assesses use of ITNs within the household • Indicator is representative of the national and regional population. • Comparable across countries if appropriate and consistent sampling procedures are followed.
Limitations	• Usually collected only every three to five years, as part of large nationally representative surveys. • The survey period may not coincide with the ITN distribution campaigns, causing ITN use to be underestimated. • Nationally representative surveys are powered to present results at the provincial or regional level and cannot provide accurate estimates for lower levels (i.e. district, county, health facility).

[13] Roll Back Malaria Monitoring and Evaluation Reference Group Survey and Indicator Task Force (2018). Household Survey Indicators for Malaria Control. https://www.malariasurveys.org/documents/Household%20Survey%20Indicators%20for%20Malaria%20Control_FINAL.pdf

1.3.5 ITN Use to Access Ratio

Indicator: ITN Use to Access Ratio

Numerator: ITN Use: Proportion of the population that slept under an ITN the night before the survey

Denominator: ITN Access: Proportion of population with access to an ITN in their household

✓ **Established**

Indicator Source: Koenker H, Ricotta E, Olapeju B, Choiriyyah I. October 2018. Insecticide-Treated Nets (ITN) Access and Use Report. Baltimore, MD. PMI VectorWorks Project, Johns Hopkins Center for Communication Programs.

Data Sources: This indicator is usually available through nationally representative household surveys, such as DHS or MIS. DHS and MIS data is available at: https://dhsprogram.com/Data/ . It can also be collected as part of special evaluation studies.

Considerations & Interpretations:

- This indicator is a ratio of two other indicators: ITN use and ITN access. While it is a ratio of two indicators, it is often presented as a percentage.
- This indicator provides data on the behavioral gap for net use rather than a gap because not enough ITNs are available. This analysis is useful for informing ITN programs whether they need to focus on achieving higher ITN coverage, promoting ITN use or both. The closer the ratio is to 1 or 100%, the smaller the behavioral gap in net use (i.e. the fewer people in the population with access to an ITN but not using it).

Table 1.3.5. Strengths and Limitations

Strengths	• Useful for information to focus programmatic efforts on behavior change to increase ITN use, increasing ITN coverage or both. • Indicator is representative of the national and regional population. • Comparable across countries if appropriate and consistent sampling procedures are followed.
Limitations	• Usually collected only every three to five years, as part of large nationally representative surveys. • The survey period may not coincide with the ITN distribution campaigns, causing ITN use to be underestimated. • Nationally representative surveys are powered to present results at the provincial or regional level and cannot provide accurate estimates for lower levels (i.e. district, county, health facility).

1.3.6 Mass Campaign ITN Distribution Coverage

Indicator: Mass campaign ITN distribution coverage (Proportion of the population protected by ITNs, based on mass ITN distribution)

Numerator: Number of ITNs distributed in past 3 years through mass campaigns, multiplied by 2

Denominator: Total estimated population

Indicator Source: Adapted from: World Health Organization. 2017. Achieving and maintaining universal coverage with long-lasting insecticidal nets for malaria control. Pg. 1.

Adapted

Indicator Source: Adapted from: World Health Organization (2018). Malaria surveillance, monitoring & evaluation: a reference manual. Geneva: World Health Organization. Pg. 186.

Data Sources: The number of ITNs distributed can be obtained from the NMCP staff or implementing partners supporting ITN distribution. Population estimates may either be available in DHIS2 or through national statistical sources such as projected census reports, from household enumerations conducted prior to ITN distribution, or through geospatial sources, such as WorldPop or Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) (WorldPop, 2021; Wardrop, 2018). Whenever possible, data sources should be triangulated to guide the selection process. When values differ between sources, consultation with stakeholders is recommended to review key underlying data and assumptions (base year, annual growth rates and other adjustments), correct any errors, identify the most appropriate population data source or sources. In some cases, it may be preferable to prepare population coverage estimates using more than one data source, thus generating an estimated range of population coverage, to generate confidence in the population protected estimates.

Considerations & Interpretations:

- The World Health Organization recommends that NMCPs distribute "one net for every two persons at risk of malaria."14 The mass campaign ITN distribution indicator can show whether enough ITNs were distributed during a mass campaign to cover the population with 1 net for every 2 persons and can highlight any gaps in the distribution.
- This data is usually available down to the district level. However, unlike the ITN ownership, access and use indicators above, it does not provide detail on the availability and use of ITNs at the household level.
- This indicator should be present with a description of any contextual details that inform its interpretation, including:
  - if selected sub-areas within a country were targeted for this campaign or excluded, this should be clearly noted.
  - if there are known or suspected population movements, such as migration due to civil unrest or population influx due to economic opportunities (i.e. opening of a mine).

Table 1.3.6. Strengths and Limitations

Strengths	• Usually available country-wide and to the district level. • Can help to identify successes and gaps in ITN distribution.
Limitations	• Only assesses the ITNs distributed, not the proportion of nets that are currently available or in use.

[14] World Health Organization. 2017. *Achieving and maintaining universal coverage with long-lasting insecticidal nets for malaria control.* Pg. 1. https://apps.who.int/iris/bitstream/handle/10665/259478/WHO-HTM-GMP-2017.20-eng.pdf?sequence=1

1.3.7 ANC ITN Distribution Coverage

Indicator: ANC ITN distribution coverage (Proportion of pregnant women attending first antenatal care (ANC1) visit who received an ITN during their ANC visit)

Numerator: Number of pregnant women who received an ITN during their first ANC visit

Denominator: Total pregnant women attending first ANC visit

Adapted

Indicator Source: Adapted from: World Health Organization. 2013. Vector Control Technical Expert Group. Report to MPAC: Methods for maintaining coverage with long-lasting insecticidal nets (LLINs). Pg. 7.

Data Sources: The number of ITNs distributed through ANC and the number of ANC visits can be obtained from national health information systems, such as the DHIS2 available in many countries.

Considerations & Interpretations:

- This indicator assesses whether women who attended their first ANC visit received an ITN. Without additional information, such as ITN stock data, it cannot detail why the women did not receive an ITN.
- ANC ITN distribution coverage does not reflect the true coverage of ITNs among pregnant women in the population because:
  - most reports are from the public health sector;
  - the proportion of pregnant women who attend public health facilities for ANC (from which most data are derived) may differ by area and over time;
  - health facility reporting rates may differ by area.

Table 1.3.7. Strengths and Limitations

Strengths	• Usually available country-wide, per month and at the health facility level. In some countries available at the weekly and community level. • Assesses ITN distribution through ANC.
Limitations	• Only assesses whether ITNs were distributed through ANC, not the proportion of ITNs that are currently available or in use. • Cannot determine the reason why ITNs may not be distributed. • Biased by proportion seeking treatment at public health facilities and health facility reporting rates.

1.3.8 EPI ITN Distribution Coverage

Indicator: EPI ITN distribution coverage (Proportion of infants 0-11 months attending the expanded program on immunization (EPI) who received an ITN during their EPI visit)

Numerator: Number of infants 0-11 months attending EPI who received an ITN during their EPI visit

Denominator: Total infants 0-11 months attending EPI visit

Adapted

Indicator Source: Adapted from: World Health Organization. 2013. Vector Control Technical Expert Group. Report to MPAC: Methods for maintaining coverage with long-lasting insecticidal nets (LLINs). Pg. 7.

Data Sources: The number of ITNs distributed through EPI and the number of EPI visits can be obtained from national health information systems, such as the DHIS2 available in many countries.

Considerations & Interpretations:

- This indicator assesses whether infants who attended their EPI visit received an ITN. Without additional information, such as ITN stock data, it cannot detail why infants did not receive an ITN.
- EPI ITN distribution coverage may not reflect the true coverage of ITNs among infants in the population because:
  - most reports are from the public health sector;
  - the proportion of infants who attend public health facilities for EPI (from which most data are derived) may differ by area and over time;
  - health facility reporting rates may differ by area.

Table 1.3.8. Strengths and Limitations

Strengths	• Usually available country-wide, per month and at the health facility level. In some countries available at the weekly and community level. • Assesses ITN distribution through EPI.
Limitations	• Only assesses whether ITNs were distributed through EPI, not the proportion of nets that are currently available or in use. • Cannot determine the reason why ITNs may not be distributed. • Biased by proportion seeking treatment at public health facilities and health facility reporting rates.

1.3.9 ANC AND EPI ITN POPULATION DISTRIBUTION COVERAGE

Indicator: ANC and EPI ITN population distribution coverage (Proportion of estimated pregnant women and infants 0-11 months who received an ITN during their ANC or EPI visit)

Numerator: Number of pregnant women and infants 0-11 months who received an ITN during their ANC or EPI visit

Denominator: Total estimated pregnant women and infants 0-11 months based on population projections

Indicator Source: Adapted from: World Health Organization. 2013. Vector Control Technical Expert Group. Report to MPAC: Methods for maintaining coverage with long-lasting insecticidal nets (LLINs). Pg. 7.

Data Sources: The number of ITNs distributed through ANC and EPI visits can be obtained from national health information systems, such as the DHIS2 available in many countries. Population estimates may either be available in DHIS2 or through national statistical sources such as projected census reports, or from household enumerations for specific interventions.

Considerations & Interpretations:

- This indicator uses population estimates to determine the total percentage of the vulnerable populations of pregnant women and infants 0-11 months who received an ITN through a health facility. Reviewed alongside the ANC and EPI ITN distribution coverage indicators, this population-based estimate can help to determine whether individuals not receiving ITNs is due primarily to non-attendance at health facilities or not receiving ITNs when they do attend.
- Interpreting coverage based on population estimates: Population estimates are often projections from census. Due to population growth and human migration, whether permanent or seasonal, population estimates may not truly reflect the population within a given area. The variations can become more pronounced at the more granular levels of health facility or community. Thus, at lower levels it becomes more likely that the estimates of the vulnerable population receiving an ITN during a health facility visit are higher or lower than the true population receiving nets.

Table 1.3.9. Strengths and Limitations

Strengths	• Usually available country-wide, per month and at the health facility level. In some countries available at the weekly and community level. • Provides a population coverage estimate that can be used to track against national targets and compare to other vector control or malaria prevention interventions.
Limitations	• Only assesses whether ITNs were distributed through ANC and EPI, not the proportion of nets that are currently available or in use. • Cannot determine the reason why ITNs may not be distributed. • Biased by proportion seeking treatment at public health facilities and health facility reporting rates. • Limited by the accuracy of the population estimates.

1.3.10 ITN Population Distribution Coverage Through All Channels

Indicator: ITN Population distribution coverage through all channels (Proportion of population at risk potentially covered by ITNs distributed)

> **Numerator:** Number of ITNs distributed in past 3 years through all channels, including mass campaigns, ANC/EPI, school-based distribution and community-based campaigns, multiplied by 2
>
> **Denominator:** Total estimated population at risk of malaria

Adapted

Indicator Source: Adapted from: World Health Organization (2018). Malaria surveillance, monitoring & evaluation: a reference manual. Geneva: World Health Organization. Pg. 186.

Data Sources: The number of ITNs distributed through each channel can be obtained from various data sources. ITNs distributed through ANC and EPI visits can be obtained from national health information systems, such as the DHIS2 available in many countries. ITNs distributed through mass campaigns, school-based, or community-based distribution campaigns, can be obtained from the NMCP staff or implementing partners supporting the ITN distributions. In some cases, this information is also entered into the national DHIS2. Population estimates may either be available in DHIS2 or through national statistical sources such as projected census reports, or from household enumerations conducted prior to ITN distribution.

Considerations & Interpretations:

- The World Health Organization recommends that NMCPs distribute "one net for every two persons at risk of malaria."[15] This indicator can show whether enough ITNs were distributed through all channels (including mass campaigns, school-based or community-based distributions, and ANC and EPI facility-based distributions) to cover the population with 1 net for every 2 persons. This indicator can help highlight any locations that may have gaps in distribution. When interpreting this indicator, one would look for a percentage at or above 100% for each area at risk of malaria.

Table 1.3.10. Strengths and Limitations

Strengths	• Provides an overview of whether the minimum number of required ITNs required to protect the population are being distributed. • Provides a population coverage estimate that can be used to track against national targets and compare to other vector control or malaria prevention interventions.
Limitations	• Only assesses the potential population coverage based on all ITNs distributed, not the proportion of nets that are currently available or in use. • Since it totals the number of ITNs distributed over the past three years, is likely an overestimate of the true population protected. Over time, ITNs are lost, torn or no longer used. • Can only be summarized at the lowest level that data is available across all sources. • Cannot determine the reason why ITNs may not be distributed at adequate levels to cover the population. • Limited by the accuracy of the population estimates.

[15] World Health Organization. 2017. *Achieving and maintaining universal coverage with long-lasting insecticidal nets for malaria control.* Pg. 1. https://apps.who.int/iris/bitstream/handle/10665/259478/WHO-HTM-GMP-2017.20-eng.pdf?sequence=1

1.4 VECTOR DENSITY

Purpose/Rationale: The purpose of the vector density indicator is to determine the seasonality of transmission, the optimal timing of interventions based on transmission season(s), and the impact of vector control interventions.

1.4.1 VECTOR DENSITY

Indicator: Vector density (Number of adult female *Anopheles* malaria vectors, disaggregated by species, collected per sample collection - collections and unit time)

Numerator: Number of adult female *Anopheles* malaria vectors collected, disaggregated by species

Denominator: Number of sample collections

✓ **Established**

Indicator Source: World Health Organization. 2018. Malaria surveillance, monitoring & evaluation: a reference manual. Geneva: World Health Organization. Pg. 89.

Data Sources: This indicator is usually available through entomological surveillance studies.

Considerations & Interpretations:

- Vector density is commonly collected where entomological monitoring is implemented and is often used to examine impact of vector control interventions that are intended to reduce the vector population. It is typically an indicator that can be estimated in most endemic settings. While other key indicators, such as sporozoite rate and entomological inoculation rate (EIR) are more closely related to malaria transmission, they may require large sample sizes that may not be feasible to collect in some settings. In addition, these measures may not show enough variation to assess the impact of vector control interventions.
- Vector density can be thought of as a superindicator for assessing total vectors that includes several other indicators, depending upon the data collection method. For example, vector density collected through human landing catch produces human biting rates, biting time, and biting location. Vector density collected through pyrethrums spray catches produces indoor resting density. Vector density can also be used to calculate vector occurrence and species composition. While many different sample collection methods can be used, each method should be presented separately as vector densities are not comparable across methods.[16]
- Samples should be collected on a routine basis throughout the transmission season.

Table 1.4.1. Strengths and Limitations

Strengths	• Allows the ability to determine the seasonality of vectors, and thus, transmission risk. • Can be used to assess the impact of vector control interventions on vector populations.
Limitations	• Not easily comparable across collection methods.

[16] Malaria Elimination Initiative. (2020). *Entomological Surveillance Planning Tool.* San Francisco: The Global Health Group, University of California, San Francisco.

1.5 INSECTICIDE SUSCEPTIBILITY

Purpose/Rationale: The purpose of the insecticide susceptibility indicators is to guide selection of tools or products that are effective against the wild vector populations.

1.5.1 INSECTICIDE SUSCEPTIBILITY

Indicator: Insecticide susceptibility (Proportion of adult female *Anopheles* malaria vectors dead after exposure to a discriminating concentration of insecticide ± synergist)

Numerator: Number of dead or incapacitated adult female *Anopheles* malaria vectors

Denominator: Total number of adult female *Anopheles* malaria vectors exposed to a discriminating concentration of insecticide in standard bioassays or insecticide plus synergist assay

✓ **Established**

Indicator Source: World Health Organization. 2018. Malaria surveillance, monitoring & evaluation: a reference manual. Geneva: World Health Organization. Pg. 90.

Data Sources: This indicator is usually available through entomological surveillance studies using WHO tube tests or CDC bottle bioassays.[17] Some of this data can be found online at IR Mapper (https://www.irmapper.com/) and through data collected by Moyes et al.[18] and available online (https://doi.org/10.5061/dryad.dn4676s).

Considerations & Interpretations:

- Per WHO standards, insecticide susceptibility is classified as:
  - < 90% = confirmed resistance;
  - 90–97% = possible resistance;
  - ≥ 98% = susceptibility.[19]
- At least 100 mosquitoes per species should be exposed in a given sample per insecticide tested.[19]
- The results should be presented separately for each species.
- When calculating insecticide susceptibility, results may need to be adjusted for using Abbott's formula. Specifically, a set of control mosquitoes should be kept during the period of insecticide susceptibility evaluation. "If 24-hr mortality in controls exceeds 20% using WHO tube assays, all results from that day's tests must be discarded. If mortality in the control is between 5-20%, results must be corrected for control mortality using Abbott's formula. Control mortality is assessed at 2 hours using the CDC bottle assay. When control mortality is > 10%, test results should be discarded; use Abbott's formula to correct for control mortalities of 3 to 10%."[19] Abbot's formula is calculated as [(% control living - % exposed living) /% control living] X 100%.
- In cases where it is difficult to obtain adequate samples of mosquitoes for susceptibility testing, the insecticides currently in use or most likely to be used in the future should be prioritized for testing.

Table 1.5.1. Strengths and Limitations

Strengths	• Supports the selection of insecticides for IRS and ITNs.
Limitations	• In lower transmission areas, it may be difficult to obtain adequate samples of mosquitoes for susceptibility testing. Results from smaller samples can be difficult to interpret.

[17] World Health Organization. 2016. Test procedures for insecticide resistance monitoring in malaria vector mosquitoes – 2nd ed. Geneva: World Health Organization. https://www.who.int/malaria/publications/atoz/9789241511575/en/

[18] Moyes, C.L., Wiebe, A., Gleave, K. et al. Analysis-ready datasets for insecticide resistance phenotype and genotype frequency in African malaria vectors. Sci Data 6, 121 (2019). https://doi.org/10.1038/s41597-019-0134-2

[19] U. S. President's Malaria Initiative technical guidance: 2018 revised for FY2019 planning

1.5.2 Insecticide Susceptibility Intensity

Indicator: Insecticide susceptibility intensity (Proportion of adult female *Anopheles* malaria vectors dead after exposure to 5x or 10x discriminating concentrations of an insecticide)

Numerator: Number of dead or incapacitated adult female *Anopheles* malaria vectors

Denominator: Total number of adult female *Anopheles* malaria vectors exposed to 5x or 10x discriminating concentration of insecticide in standard bioassays

✓ **Established**

Indicator Source: World Health Organization. 2018. Malaria surveillance, monitoring & evaluation: a reference manual. Geneva: World Health Organization. Pg. 90.

Data Sources: This indicator is usually available through entomological surveillance studies using WHO tube tests or CDC bottle bioassays.[20]

Considerations:

- This indicator is intended to measure the strength of expressions of resistance phenotypes to help assess the operational significance of the resistance where detected.
- Per WHO classifications
    - < 98% after 10x exposure = high-intensity resistance;
    - ≥ 98% after 10x exposure but < 98% after 5x exposure = moderate intensity resistance;
    - ≥ 98% after 10x and 5x exposure but < 98% after 1x exposure = low-intensity resistance.[14]
- At least 100 mosquitoes per species should be exposed in a given sample.[14]
- The results should be presented separately for each species.

Table 1.5.2. Strengths and Limitations

Strengths	• Supports the selection of insecticides for IRS and ITNs, particularly useful for identifying locations for new types of nets.
Limitations	• In lower transmission areas, it may be difficult to obtain adequate samples of mosquitoes for susceptibility testing. Results from smaller samples can be difficult to interpret.

[20] World Health Organization. 2016. Test procedures for insecticide resistance monitoring in malaria vector mosquitoes – 2nd ed. Geneva: World Health Organization. https://www.who.int/malaria/publications/atoz/9789241511575/en/

1.6 IRS INSECTICIDE RESIDUAL EFFICACY

Purpose/Rationale: The purpose of the IRS insecticide residual efficacy is to determine the period of time the IRS insecticide remains effective against malaria vectors.

1.6.1 IRS INSECTICIDE RESIDUAL EFFICACY

Indicator: IRS insecticide residual efficacy (Percent of adult female *Anopheles* malaria vectors who died after exposure to insecticide on treated surface in the field.)

Numerator: Number of adult female *Anopheles* malaria vectors who died after exposure to insecticide on treated surface in field.

Denominator: Total number of adult female *Anopheles* malaria vectors exposed to treated surface in the field.

✓ **Established**

Indicator Source: World Health Organization. 2006. Guidelines for testing mosquito adulticides for indoor residual spraying and treatment of mosquito nets. Geneva: World Health Organization. Pg. 13-14.

Data Sources: This indicator is usually available through entomological surveillance studies using cone wall bioassays.

Considerations & Interpretations:

- The purpose of this indicator is to estimate the time period that the IRS product remains effective against the vectors. The WHO standard is to have above 80% mosquito mortality for the product to be considered effective. Samples are tested one week after spraying, and then every month until mosquito mortality drops below 80%.21
- Data can be disaggregated by the wall type (i.e. cement, mud, painted), or the lowest value across wall types can be used to create a summary indicator. If the most common type of wall in the sprayed area is known, this can help in the analysis and interpretation of results.
- The recommended exposure period for residual efficacy tests varies by chemical.
- Residual efficacy has a wide variance across settings, years, and sprayable surfaces.22
- When reporting residual efficacy, the mosquito source (locally collected vs. lab reared), should always be noted, as the results and interpretation can differ according to the source.

Table 1.6.1. Strengths and Limitations

Strengths	• Supports the selection of insecticides for IRS. • Can help with the interpretation of impact of IRS on malaria case incidence.
Limitations	• Presented as a continuous variable, can be difficult to summarize and interpret for decision-makers. • Residual efficacy results can vary widely across settings, years, and sprayable surfaces, making results more difficult to interpret.

[21] World Health Organization. 2006. *Guidelines for testing mosquito adulticides for indoor residual spraying and treatment of mosquito nets.* Geneva: World Health Organization; https://apps.who.int/iris/bitstream/handle/10665/69296/WHO_CDS_NTD_WHOPES_GCDPP_2006.3_eng.pdf

[22] Dengela, D., Seyoum, A., Lucas, B. et al. 2018. *Multi-country assessment of residual bio-efficacy of insecticides used for indoor residual spraying in malaria control on different surface types: results from program monitoring in 17 PMI/USAID-supported IRS countries.* Parasites Vectors (2018) 11: 71. https://doi.org/10.1186/s13071-017-2608-4

1.6.2 IRS Insecticide Residual Efficacy Months

Indicator: IRS insecticide residual efficacy months (Number of months for which IRS insecticide residual efficacy remains above 80%)

Numerator: N/A

Denominator: N/A

✓ **Established**

Indicator Source: World Health Organization. 2006. Guidelines for testing mosquito adulticides for indoor residual spraying and treatment of mosquito nets. Geneva: World Health Organization. Pg. 13-14.

Data Sources: This indicator is usually available through entomological surveillance studies using cone bioassays.

Considerations & Interpretations:

- This indicator uses the continuous IRS insecticide residual efficacy indicator and creates a binary indicator for each month, where the value is above or below the 80%.
- Data can be disaggregated by the wall type (i.e. cement, mud, painted), or the lowest value across wall types can be used to create a summary indicator. If the most common type of wall in the sprayed area is known, this can help in the analysis and interpretation of results.
- The recommended exposure period for residual efficacy tests varies by chemical.
- Residual efficacy has a wide variance across settings, years, and sprayable surfaces.[23]
- When reporting residual efficacy, the mosquito source (locally collected vs. lab reared), should always be noted, as the results and interpretation can differ according to the source.

Table 1.6.2. Strengths and Limitations

Strengths	• Easier to interpret and compare across insecticides. • Supports the selection of insecticides for IRS. • Can help with the interpretation of impact of IRS on malaria case incidence.
Limitations	• Residual efficacy results can vary widely across settings, years, and sprayable surfaces, making results more difficult to interpret.

[23] Ibid.

1.7 CLIMATOLOGICAL INDICATORS

Purpose/Rationale: The purpose of the climatological indicators is to better understand the vector control intervention context, and climate factors that may independently affect the malaria burden from year to year.

1.7.1 MEAN PRECIPITATION

Indicator: Mean precipitation (Average precipitation within a given area over a period of time.)

Newly Developed or Proposed

Indicator Source: No previously documented indicator source.

Data Sources: Precipitation data is freely available online from the Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS) (https://www.chc.ucsb.edu/data/chirps/). Data from government meteorological departments may also be available. The specific precipitation sources can be chosen based on the level of detail required for the analyses. For example, CHIRPS data is available at 4 km spatial resolution and are composited in daily, 5-day, 10-day, and monthly units.

Considerations & Interpretations:

- Precipitation data is available as a spatial file. In order to effectively use precipitation data valid administrative boundaries must be available to match to the precipitation data.

Table 1.7.1. Strengths and Limitations

Strengths	• Can help to explain increases or decrease in vector density and malaria case incidence form year to year.
Limitations	• Difficult to use at lower levels, such as the health facility catchment level, where documented administrative boundaries are not available.

1.7.2 Mean Enhanced Vegetation Index

Indicator: Mean enhanced vegetation index (Average enhanced vegetation index within a given area over a period of time.)

Newly Developed or Proposed

Indicator Source: No previously documented indicator source.

Data Sources: The enhanced vegetation index data is freely available online from the United States Geological Survey (USGS) (https://modis.gsfc.nasa.gov/data/dataprod/mod13.php).

Considerations & Interpretations:

- The enhanced vegetation index is a measure used to characterize range of vegetation states and is calculated from the visible and near-infrared light reflected by vegetation. Values range from -1 to 1, with healthy vegetation values varying between 0.2 and 0.8. Very low values (0.1 and below) correspond to barren areas (rock, sand, snow). High values (0.6 – 0.8) correspond to temperate and tropical rainforests. The EVI improves upon the Normalized Difference Vegetation Index (NDVI) by correcting some atmospheric conditions, minimizing canopy-soil variations, and improving sensitivity over dense vegetation conditions.
- The enhanced vegetation index is available as a spatial file. In order to effectively use the enhanced vegetation index data valid administrative boundaries must be available.

Table 1.7.2. Strengths and Limitations

Strengths	• Can help to explain increases or decrease in vector density and malaria case incidence form year to year.
Limitations	• Difficult to use at lower levels, such as the health facility catchment level, where documented administrative boundaries are not available.