Field Epidemiology
IN ACTION

Case Study

Outbreak Investigation in the Field

Contents

Note: If this case study includes any technical terms which you may not understand, refer to the Field Epidemiology in Action reference guide which provides general epidemiology definitions. The Field Epidemiology Reference Guide document is available at: https://www.fieldepiinaction.com/reference-guide. If you wish to explore the topics covered in this case study, there is an outbreak investigation eLearning course on the Field Epidemiology in Action website: https://www fieldepiinaction.com/outbreak-investigation. All people, places and scenarios contained in this case study are fictional.

1

Background

You are a provincial public health surveillance officer located at the Provincial Hospital, in the coastal capital city of your home island province.

On Tuesday morning January 11th 2022 at 10:30am, you receive a phone call from Dorothy, a nursing officer in a rural community health post located in Green Hills District. Green Hills is a mountainous area of your province, with a generally cool, wet climate. Accessing the area is difficult, especially during the wet season at the moment, when the few dirt roads are very difficult to pass in a vehicle. The nearest district health centre is at Blue Rivers Crossing, three hours' drive away on a poor dirt road with several river crossings, down into a neighbouring valley. The nearest District Hospital is a further two hours' drive away along the same road.

Nurse Dorothy is seeking your advice about some concerning cases of fever they've seen in recent days.

Nurse Dorothy tells you she's quite concerned, because earlier this morning a worried local family from nearby Alpha village presented to the community health post with a three-year-old female child who appeared very unwell. The child has high fever, chills, vomiting, dehydration, confusion and general weakness. This started two or three days ago.

This was the third young child presenting with similar signs, particularly fever and chills that Nurse Dorothy has seen at the local health post since last Friday (January 7th). The previous two children (five and seven-years old) are siblings from another family who also live in Alpha village in a house close to the sick child that she's attended to this morning.

Nurse Alice was on duty at the facility over the weekend. Early Monday morning, Nurse Alice provided a handover to Nurse Dorothy, and reported attending to several patients over the weekend. These included two young people who presented with similar complaints of fever, chills, body aches and pains, sweating and headache lasting several days. The first was a pregnant female from Alpha village who came into the health post on Saturday. The pregnant woman specifically complained of night sweats, vomiting and diarrhoea, and seemed very weak. Nurse Alice provided her with supportive treatment for fever and dehydration, and recommended that she return for a follow up visit in two days, especially if her symptoms continued or got worse. The second patient was a young adult male in his early twenties from the neighbouring Bravo village two kilometres away, who presented late on Sunday afternoon.

Figure 1: Depiction of terrain in Green Hills District, Highlands region.

Whilst it is not uncommon for patients to present with fever and weakness in their district, Nurse Dorothy and her colleagues do not recall having previously seen so many cases of acute fever in such a short space of time.

Nurse Dorothy says:

"I'm worried that there may be something unusual going on with these sick patients. Do you think these fever cases may be some sort of outbreak? And do you have any advice about the next steps that my colleagues and I should take here at the health post?"

As a trained field epidemiologist, you recall there are eight steps to conducting an outbreak investigation.

The 8 key outbreak investigation steps include:

1. Confirm an outbreak
2. Try to establish a diagnosis
3. Make an outbreak case definition
4. Find cases and obtain information
5. Make a linelist
6. Describe and interpret the data
7. Implement control measures*
8. Communicate findings

***Control measures can be implemented at any point in the investigation, and should be put in place as soon as possible.**

In addition, to help determine your next investigation steps, you remember to refer to the Pacific Outbreak Manual (1) for additional response guidelines for core syndromic surveillance conditions, specifically, clusters of **prolonged fever** cases.

2

Confirm an outbreak

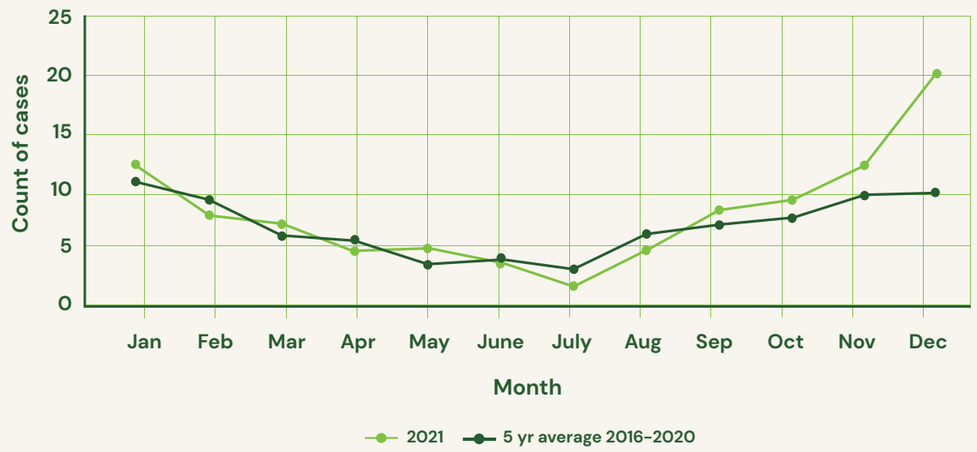
You thank Nurse Dorothy for the information she has provided, and request further follow up by the community health post team, to:

1. Enquire about the health status of all five fever cases they've seen from villages Alpha and Bravo in the past week;
2. Review their health post's medical records to determine if any similar cases have presented in the past three months; and
3. Contact their colleagues from the neighbouring community health posts to ask if they've also seen an apparent increase in cases of unspecified prolonged fever illness in recent days or weeks.

You arrange to call Nurse Dorothy back the next day to exchange additional information. You also agree to support the planning and logistics for the transport to the Blue Rivers Crossing District Health Centre and treatment of the severely unwell child she saw this morning if needed, to receive an update about their medical records review, and any possible updates from neighbouring community health posts.

In the meantime, you refer to the Ministry of Health's provincial-level aggregated syndromic surveillance notifications data, which is usually updated weekly. Although there have been some delays in data reporting for the month of January, you notice an increase of unspecified prolonged fever cases reported from the **Green Hills District** for the preceding month of December, compared to the same time period in the previous five years.

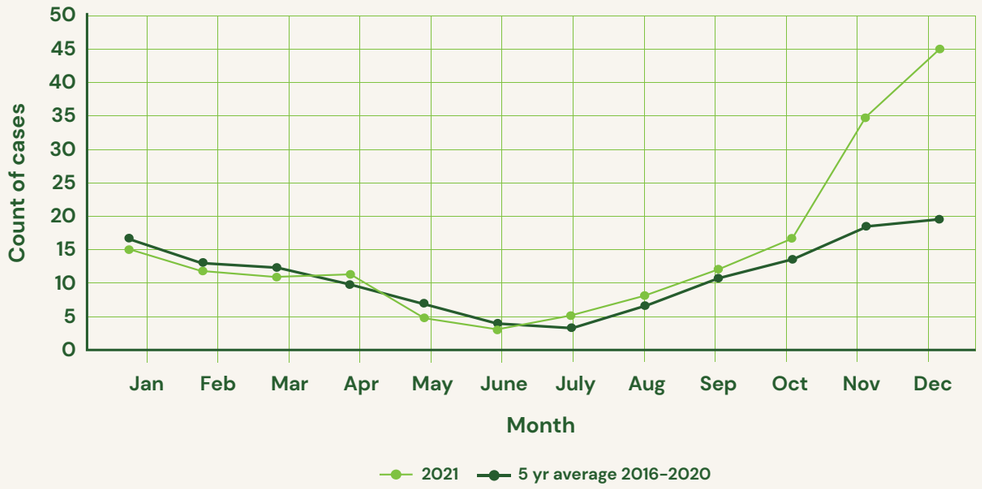
Figure 2: Syndromic surveillance data for prolonged fever in Green Hills District, 2016-2021.



So, Nurse Dorothy's feeling about something unusual happening may indeed be correct!

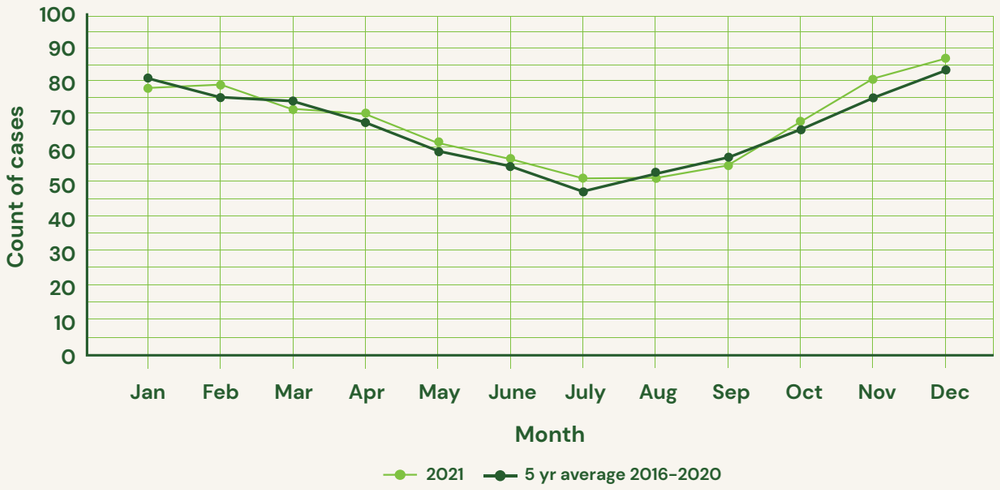
For comparison, you decide to also look at the data from neighbouring **Valley District**, where the district hospital is located. Again, you notice a similar pattern of increasing notifications of unspecified prolonged fever cases in November and December 2021, compared to the same period in previous years. Case counts are generally higher than in Green Hills District, which makes sense because the population is larger in Valley District, with two towns and large farming communities in the valley.

Figure 3: Syndromic surveillance data for prolonged fever in Valley District, 2016-2021.



You also look at unspecified prolonged fever illness notifications for the **Capital District**, a low-lying coastal urban region where the capital city and provincial hospital is located. You notice that the number of unspecified prolonged fever illness cases is generally much higher here than both Valley and Green Hills Districts. Although the seasonal pattern of decreased notifications during the dry season (May to July) is similar, there is no obvious increase in case numbers for the previous two months of November and December 2021, compared to Valley and Green Hills Districts.

Figure 4: Syndromic surveillance data for prolonged fever in Capital District, 2016-2021.



These findings further raise your suspicion that an outbreak of a fever syndrome may be occurring in the rural districts of Valley and Green Hills. You decide to call your colleague Peter, the district focal point for public health surveillance at Valley District Hospital to further discuss these findings. You are specifically interested to know if Peter may have any information about a possible **diagnosis**.

3

Establish a diagnosis

You call your colleague Peter at the Valley District Hospital, who is interested in your observations of the district-level data and news from the community health post servicing Alpha and Bravo villages.

Peter says:

This is an interesting report from the highlands region. We've also seen a recent increase in fever cases notified here at Valley District Hospital. We've heard similar rumours from our colleagues in Green Hills District, at Blue Rivers Crossing District Health Centre. The health staff working here are always worried about illnesses like typhoid or leptospirosis, especially because it's the wet season, which has been unusually hot and humid this year. Most of our recent fever cases have been in local people from Valley District, but we also noticed that quite a few of the earliest cases were in construction workers who've been brought in from the capital to upgrade the Highlands Highway. Some hospital health staff were wondering if they may have brought some kind of infectious illness from the capital? We continued seeing fever cases, so we managed to get blood samples from some more recent cases. Turns out, some samples tested positive for malaria. There are definitely a lot of mosquitoes around this year."

You realise that Peter's information may have provided an important clue!

You know that malaria is a mosquito-borne parasitic disease which is common in the low-lying coastal regions of your island province. There are typically two species of malaria detected here: *Plasmodium vivax* and *Plasmodium falciparum*. Whilst *P. vivax* is prevalent and can result in chronic infection, malaria caused by the *P. falciparum* parasite is typically more acutely dangerous, as it can result in severe complications and life-threatening disease. This is especially true in communities with no background immunity, and in high-risk patients like pregnant women and young children. Considering that malaria is not an endemic disease in the cooler mountainous regions of your province, it may not have been the first or most obvious cause of fever for Nurse Dorothy and her colleagues from the community health post to consider.

Early the next day, you call back Nurse Dorothy at the community health post for an update. You advise Nurse Dorothy that the next steps include:

1. Try to diagnose a cause(s) of the cases' fever syndrome;
2. Determine if these cases are indeed due to the same cause; and
3. If the cases appear to be linked or connected in some way (e.g. same location, family relations, onset of illness, exposure histories, etc.)

Thankfully, Nurse Dorothy and her dutiful colleagues have already started some of this work!

Nurse Dorothy tells you that they followed up with two of the five fever cases they've seen since late last week. The pregnant woman seen over the weekend was still feeling very unwell, and returned for a follow-up visit as advised. As part of the health post's primary health care follow-up protocol, she was tested and returned a positive result for **malaria** on a **rapid diagnostic test (RDT)**.

Based on this finding, Nurse Dorothy realised it would be important to also conduct a RDT on the sick child she examined yesterday morning. Thankfully, the health post still had some extra RDTs available which Nurse Alice brought back from her last visit to the District Health Centre in Blue Rivers Crossing town a few months ago. Nurse Dorothy informs you that this child has also just returned a positive malaria RDT result!

Figure 5: Malaria rapid diagnostic test (RDT).

You now have two likely cases of malaria diagnosed within a short period of time at a rural community health post, in a mountainous highlands region not known to be endemic for malaria.

Based on this new information, you now consider an outbreak likely and urge Nurse Dorothy and her colleagues to:

1. Follow up with and test the remaining three fever cases they've seen in the past week, if possible;
2. Start to conduct active surveillance (case finding) in the villages serviced by their community health post by going house-to-house and identifying any community members with acute or prolonged fever and testing them using RDTs;
3. You also remind Nurse Dorothy to conduct a medical records review to try and identify earlier possible febrile cases, when possible; and
4. Engage with community leaders to encourage their communities to be aware of any acute or prolonged fever and to present to the health facility if they develop these symptoms, and to provide education on mosquito bite prevention.

Nurse Dorothy says:

"Neither the pregnant woman or the young child are showing any signs of improvement. I'm getting concerned about their condition. I think it may be best to arrange for them to be transported down into the valley for additional testing and treatment. We have some anti-malaria drug stocks that have nearly expired, but we're not equipped to treat very ill people here at our health post, especially if it's a severe malaria case with complications."

"I will also follow up with the two children I treated late last week, and ask Nurse Alice to try to find out more about the man from Bravo village she treated on Sunday afternoon. We'll also spread the word in our area for any persons with prolonged fever-like illness to come to the community health post for examination. But I'm also worried about our testing capacity, because we have only a handful of RDTs left."

You agree about the importance of further testing and treatment of these cases, and acknowledge Nurse Dorothy's concern about the lack of RDTs and medications at the community health post.

You assist the health post arrange for transport of the two severely ill patients to the nearest District Health Centre at Blue Rivers Crossing, and help arrange for additional RDTs and anti-malaria medications, specifically artemisinin-based combination therapy (ACT) drugs to be transported up to Nurse Dorothy's health post. Considering that an outbreak now seems very likely, and may potentially affect a larger area than just Nurse Dorothy's community health post catchment, you decide to work with your district colleagues to develop an **outbreak case definition** to help everyone accurately and consistently identify and count cases across the various community health posts and centres in the Green Hills and Valley districts.

You inform your supervisor and the Provincial Health Department Director about the likely outbreak of malaria and the steps you are taking.

4

Make an outbreak case definition

The next day, you call each of the district surveillance colleagues in the province to raise awareness of the increase in fever notifications in Green Hills and Valley Districts, and to develop an outbreak case definition. As a starting point, you refer to the **Pacific Outbreak Manual** which includes proposed case definitions for prolonged fever syndrome, as well as for malaria.

During the call with Peter from Valley District Hospital, he reports the following new information:

1. The recently microscopically-tested finger-prick blood samples revealed the presence of parasites on a thin blood smear, which the laboratory technician at Valley District Hospital identified as being the malaria parasite, *Plasmodium falciparum*.
2. Based on their hospital records review, the earliest cases diagnosed with *P. falciparum* malaria were two construction workers who reported their symptoms to have started in the first week of November, shortly after traveling from the provincial capital city to the valley to start their six-week work shifts on the highway reconstruction project.
3. The following week, an additional three road workers also presented with fever, and then tested positive for malaria by RDT. This finding raised further concern at the hospital, considering that malaria is not considered endemic in the district.

Based on this information, the team agrees to consider all cases with a symptom onset on or after Sunday, 31 October (the start of epidemiological week 44 of the previous year) as a starting point for the outbreak case definition.

You develop the following outbreak case definition, after considering the key issues related to person, place, time, and clinical criteria. You also consider the availability and accuracy of diagnostic tests in the various community health posts and health centres across the two affected districts which are not considered to be endemic areas for malaria.

Possible Outbreak Case

A person reporting illness in Valley or Green Hills District, with a symptom onset date on or after 31 October 2021 who has fever (defined as temperature above 38°C),

AND

Experienced two or more of the following symptoms: chills, loss of appetite, nausea, fatigue, headache, muscle and joint pain, cough, diarrhoea, anaemia, enlarged spleen, jaundice, shock, or neurological symptoms.

Probable Outbreak Case

A possible case that returns a positive result for malaria (*Plasmodium* spp) on a rapid diagnostic test (RDT).

Confirmed Outbreak Case

A possible or probable case in whom there is a positive laboratory test result with detection of *Plasmodium falciparum* malaria parasites in thick or thin blood smears.

Non-Outbreak Malaria Case

A possible or probable case for whom there is a positive laboratory test result with detection of *Plasmodium vivax* or *malariae* species parasites in thick or thin blood smears.

Note: Outbreak case definitions can change over time as more information is gathered throughout the outbreak investigation. Now that a case definition had been developed, the next step should be activating a provincial **outbreak investigation team** to respond to the developing outbreak situation.

5

Find cases and obtain information

5.1 Outbreak investigation team

Activating the outbreak investigation team includes assigning roles and responsibilities to coordinate case finding and data collection, managing logistics for patient transport and treatment, specimen shipping and laboratory testing, risk communication and community engagement, and initiating additional prevention and control measures to slow or halt the outbreak.

In talking with your colleagues in the Districts, you all agree that the outbreak team structure will comprise of the following roles at both district and provincial level:

- Incident Manager;
- Epidemiologist/Surveillance officer;
- Case management nurse;
- Laboratory officer;
- Logistics/Finance officer;
- Vector control officer;
- Risk communication officer; and
- Other relevant roles, e.g., drivers to transport sick patients, and deliver testing equipment and medication to health centres.

You agree that the outbreak team will:

- Develop a weekly Situation Report (SitRep) for reporting updates to the Ministry of Health Senior Management and other relevant Ministries.
- Establish a communication plan to share public health messages to the communities at risk, and to hold weekly coordination meetings as the response progresses.

Figure 6: Depiction of an Outbreak Investigation Team

5.2 Obtain further information

You speak with Nurse Dorothy again and she reports that her community in Green Hills District is geographically and culturally isolated. Most villagers are subsistence farmers raising pigs and growing various crops. Outside visitors are rare, however several young people have left the area in search of work in recent years, and occasionally return to visit family and friends. Family members working in larger towns or cities typically return for the holidays, special community events (e.g., funerals, weddings) and will often bring along gifts including food items, livestock, clothing and household items. They mostly travel home on public transport up through the valley on the Highlands Highway.

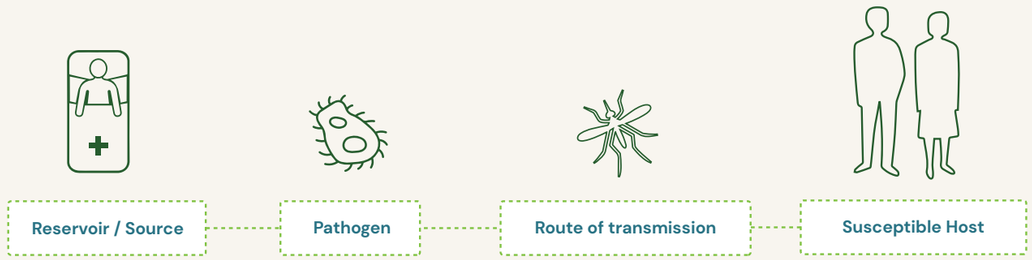
Upon further discussion and review of clinical records, the health post team recalls that they had also seen a few earlier fever cases over the recent Christmas Holiday period when lots of people came home to visit family.

The earliest of these cases was a 21-year-old man whom had returned home from the provincial capital in late December to visit his family for the Christmas Holiday period. The young man had complained of fever, chills, extreme tiredness and headache, and mentioned that he had first started feeling unwell before leaving the city for his home village. After a few days of no improvement, he visited the community health post on 26th December. He was treated with paracetamol for his fever, and provided with oral rehydration solution. The man was asked to return to the health post should his symptoms persist, however he left Alpha village before the New Year to return to his job in the capital city.

Based on this information, you suspect that this individual may have been the **primary case (the first case in a particular outbreak)** for the outbreak in the Green Hills villages. You obtain the case's contact details from Nurse Dorothy and request the provincial case management officer to follow up with the man in the capital city, to enquire about his status and condition, and to organise for his testing and treatment if necessary.

You also realise there may have been other earlier cases, who perhaps did not seek care at the community health post. However more importantly, there may also still be additional undetected cases currently in the community who are unwell. Finding these cases is critical to stopping the outbreak. Malaria spreads between infected people by the bites of mosquitoes. As a vector-borne disease, infected people serve as a **source** for the **transmission** of malaria by infected female *Anopheles* mosquitoes, who then transmit it onwards to **susceptible hosts** (other people). Therefore, treating infected patients and eliminating infected mosquitoes from the area will stop the outbreak by interrupting the chain of transmission, thereby preventing additional cases of severe illness and saving lives.

Figure 7: Malaria chain of infection.



You instruct Nurse Dorothy's team, as well as all district and provincial surveillance and case management officers to continue conducting **active case finding** to identify, test and treat additional undetected cases in their communities.

5.3 Active case finding

The next day, Nurse Dorothy reports back on news from their neighbouring community health post further up in the highlands, which she received via SMS. Nurse Dorothy says that this community health post is located at the end of the highlands road, in a very remote forested region. This health post serves a few remote villages that are several hours' hike away from the health post, high up in the mountains. Thankfully, they have not seen any recent unusual cases of fever. It seems that malaria may not yet have spread to these remote villages, perhaps because the cooler weather is not ideal for mosquitoes. This is good news, because testing and treating cases in these remote mountain forest villages would be very challenging. You thank Nurse Dorothy for this information and request that she warns her colleagues at the remote health post to stay alert for any increased signs of fever or unusual mosquito activity in their area. Nurse Dorothy promises to make sure that some RDTs that will be delivered to her health post later today, are also shared with this remote health post.

The update from Blue Rivers Crossing District Health Centre, down the road towards Valley District is somewhat different. They report having treated several cases of high fever since mid-December, a number of whom tested positive for malaria by RDT. They continue to receive reports of some sick villagers living along the highlands road down towards Valley District. Meanwhile, you also receive an update from the provincial case management officer about the young man treated at Nurse Dorothy's community health post on 26 December. The case was followed up and provided the following information:

The case says:

"My symptoms first started around 22 December, before I returned to my family home at Alpha village. I felt quite sick over Christmas and went to see Nurse Dorothy the day after Christmas. My symptoms continued until I had to travel back to the city, where I work as a mechanic. On the way back, at Blue Rivers Crossing, I stopped at the district health centre for help, because I was now feeling much worse than before. Thankfully, they did a quick test and told me I had malaria. They also gave me some medications to treat the illness. I thanked them, and then decided to continue my travel back to the capital city, because I needed to return to work. However, once I arrived back in the city, I felt so sick that I went straight to the provincial hospital, where they took some blood and also said I have malaria. I received treatment and stayed in hospital for a few days. Thankfully I feel much better now."

The surveillance and case management teams agree to:

> Make an outbreak **linelist**;
>
> Develop a **questionnaire** for use by case management nurses to interview all newly identified and previously diagnosed 'probable' and 'confirmed' cases. The case interviews will aim to obtain further information about the setting of their exposures to mosquito bites, symptoms experienced, onset dates and to identify other individuals at risk of infection, e.g., family members, friends or work colleagues.

The risk communications team agrees to:

> Develop and implement a **communications plan** to provide key information to communities at risk about malaria prevention, and to encourage people experiencing symptoms to come forward for rapid testing and early treatment.

The logistics team agrees to:

> Support the vector (mosquito) control team to start preparing for deployment on a **vector control operation**.
> The surveillance team will regularly share information with the vector control team to keep them updated on case numbers and affected villlages.

6

Make a linelist and case interview form

6.1 Linelist and data dictionary

You decide to use Microsoft Excel to make a linelist based on the outbreak case definition that has been developed. The linelist contains key epidemiological information, including:

- a unique patient identifier;
- case definition (possible, probable, confirmed);
- case demographics (age, sex, pregnancy status, village name, district, occupation);
- date of symptom onset;
- symptoms experienced;
- risk factors for mosquito bite exposure (e.g. window screens, house type);
- laboratory test results;
- treatment status;
- case outcome (e.g. recovery, death); and,
- any other variables considered relevant to your investigation

You decide to highlight the different sections of the linelist by variable category colours, to make it easier for surveillance officers to navigate the linelist.

Figure 8: Outbreak linelist.

Case_ ID	Case_ classification	Name	Age_ years	Age_ months	Sex	Village_ name	District_ name	Occupation	Onset_ date	Fever	Chills	Headache
M49	Probable	Fr Vi	25	NA	Male	Bravo	Green Hills	Farmer	12-Jan-22	Yes	Yes	Yes
M50	Probable	Sa Vi	41	NA	Male	Alpha	Green Hills	Farmer	12-Jan-22	Yes	Unknown	Yes
M51	Possible	Sa Lo	39	NA	Female	Alpha	Green Hills	Farmer	12-Jan-22	Yes	Yes	Yes
M52	Possible	Ro Va	28	NA	Male	Foxtrot	Green Hills	Farmer	16-Jan-22	Yes	Unknown	Yes
M53	Possible	Ha Re	0	6	Female	Foxtrot	Green Hills	Infant	16-Jan-22	Yes	Yes	Yes
M54	Possible	Ma Du	5	NA	Male	Foxtrot	Green Hills	School	16-Jan-22	Yes	No	No
M55	Possible	Lo Ec	66	NA	Female	Foxtrot	Green Hills	Farmer	16-Jan-22	Yes	Yes	Yes
M56	Possible	He We	23	NA	Female	Bravo	Green Hills	Farmer	16-Jan-22	Yes	Yes	Yes
M57	Possible	Ja Ho	19	NA	Female	Foxtrot	Green Hills	Farmer	16-Jan-22	Yes	Yes	Yes
M58	Possible	Da Ho	31	NA	Female	Foxtrot	Green Hills	Farmer	16-Jan-22	Yes	Unknown	No
M59	Possible	Jo Ho	51	NA	Male	Bravo	Green Hills	Farmer	19-Jan-22	Yes	Yes	Yes
M60	Possible	St Ho	0	9	Male	Alpha	Green Hills	Infant	19-Jan-22	Yes	No	Yes
M61	Possible	Ma Ve	50	NA	Male	Alpha	Green Hills	Shop owner	19-Jan-22	Yes	Yes	Yes
M62	Possible	Sh Le	36	NA	Male	Foxtrot	Green Hills	Farmer	19-Jan-22	Yes	Yes	Yes
M63	Probable	Da Jo	19	NA	Female	Foxtrot	Green Hills	Farmer	19-Jan-22	Yes	Unknown	Yes
M64	Probable	Ju Bi	0	11	Male	Charlie	Valley	Infant	19-Jan-22	Yes	Yes	No
M65	Probable	Bi Ei	17	NA	Male	Charlie	Valley	Farmer	19-Jan-22	Yes	Unknown	Yes
M66	Probable	Ed No	24	NA	Male	Echo	Valley	Farmer	20-Jan-22	Yes	Yes	Yes
M67	Probable	Da Sh	24	NA	Female	Delta	Valley	Farmer	20-Jan-22	Yes	No	Yes
M68	Probable	Wi Sm	30	NA	Female	Blue Rivers	Green Hills	Nurse	20-Jan-22	Yes	Yes	Yes
M69	Probable	Ch Ro	32	NA	Male	Blue Rivers	Green Hills	Shop owner	20-Jan-22	Yes	Yes	Yes
M70	Probable	Ju Tr	39	NA	Male	Highway	Valley	Trader	20-Jan-22	Yes	Yes	No
M71	Probable	Sc Mo	47	NA	Male	Highway	Valley	Farmer	20-Jan-22	Yes	Unknown	Yes
M72	Probable	An Al	41	NA	Male	Foxtrot	Green Hills	Farmer	20-Jan-22	Yes	Yes	Yes
M73	Probable	Pe Wo	7	NA	Male	Charlie	Valley	School	20-Jan-22	Yes	No	Yes
M74	Probable	Ja Fr	35	NA	Female	Delta	Valley	Farmer	20-Jan-22	Yes	Yes	Yes
M75	Probable	Ch Th	41	NA	Female	Delta	Valley	Farmer	21-Jan-22	Yes	Yes	Yes
M76	Probable	Jo De	0	2	Female	Echo	Valley	Infant	21-Jan-22	Yes	Unknown	No
M77	Probable	Am He	2	NA	Female	Delta	Valley	Home	21-Jan-22	Yes	Yes	Yes
M78	Probable	De Jo	28	NA	Male	Charlie	Valley	Farmer	21-Jan-22	Yes	Unknown	No
M79	Probable	Be Jo	57	NA	Female	Echo	Valley	Farmer	21-Jan-22	Yes	Yes	Yes
M80	Probable	An Jo	65	NA	Male	Blue Rivers	Green Hills	Retired	22-Jan-22	Yes	No	Yes
M81	Probable	Ca Mu	56	NA	Male	Blue Rivers	Green Hills	Farmer	22-Jan-22	Yes	Yes	Yes
M82	Probable	Pe Br	39	NA	Female	Foxtrot	Green Hills	Farmer	22-Jan-22	Yes	Yes	Yes
M83	Possible	St Wi	42	NA	Male	Foxtrot	Green Hills	Trader	22-Jan-22	Yes	Yes	Yes
M84	Possible	Ja Fl	29	NA	Female	Highway	Valley	Farmer	22-Jan-22	Yes	Unknown	Yes

You remember to always create and maintain a **data dictionary** to ensure that line list data are correctly and consistently entered by all surveillance and case management officers collecting information during case interviews.

The data dictionary shows all your colour-coded, line listed variable names, the type of variable, a description and all the options for data entry. Using a data dictionary will avoid confusion between team members entering data and make the job of data cleaning and analysis much easier.

Figure 9: Data dictionary.

Variable	Variable type	Variable description	Variable options
Case_ID	Categorical	Unique case identifier	Sequentially assign case number, M1, M2, etc.
Case_classification	Categorical	Case classification status	Possible | Probable | Confirmed | Non-outbreak | Unknown | no_data
Name	Categorical	First name, Last name, 2x2	E.g. Pe Jo for Peter Jones | no_data
Age_years	Numeric	Age in years	E.g. 0 (if < 1 year-old) | 5 | 10 | 21 | Unknown | no_data
Age_months	Numeric	If < 1 year-old (12 months) infant, age in months	E.g. 1 | 7 | 11 | | NA if > 1 year-old | Unknown | no_data
Sex	Categorical	Biological sex	Male | Female | Unknown | no_data
Pregnancy	Categorical	Is the case a pregnant female?	Yes | No | NA, if male| NA, if female infant | Unknown | no_data
Village_name	Categorical	Name of village	E.g. Alpha | Beta | Unknown | no_data
District_name	Categorical	Name of district	E.g. Green Hills | Valley | Unknown | no_data
Occupation	Categorical	Type of occupation	E.g. Road worker | Farmer | Office | School | Unemployed | no_data
Onset_date	Date	Date of sympom onset	dd/mm/yyyy | Unknown | no_data
Fever	Categorical	Did the case experience fever?	Yes | No | Unknown | no_data
Chills	Categorical	Did the case experience chills?	Yes | No | Unknown | no_data
Headache	Categorical	Did the case experience fever?	Yes | No | Unknown | no_data

6.2 Design questionnaire and conduct interviews

Back in late-January 2022, the surveillance and case management teams developed a case questionnaire. To prioritise the team's workload, a decision was reached for case management nurses to interview all newly identified and previously diagnosed 'probable' and 'confirmed' cases (but not 'possible' cases) to obtain further information about their symptoms, risk factors for exposure, treatment, and clinical outcome.

The questionnaire was first tested on a few early cases, and interviewers were provided training on how to complete the questionnaire.

Combined with all the earlier information your team has gathered during the course of the outbreak, these questionnaire data also help you to refine the outbreak hypotheses.

Figure 10: Sample outbreak investigation questionnaire

OUTBREAK INVESTIGATION QUESTIONNIARE

Name of interviewer: _____

Date of interview: ___/___/___

Case ID: _____

Case classification: [ ] Confirmed [ ] Probable

Part A: Demographic Information of cases

1. Case first Name _____ Case Last Name _____
2. If case is a child, Name of person being interviewed:_____
   Relationship to case:_____
3. Age _____ Date of birth: ___/___/____
4. Sex: [ ] Male [ ] Female
5. If female, is the case pregnant? [ ] Yes [ ] No
6. Village :_____
7. District :_____
8. Occupation :_____

Part B: Clinical information

9. Date of illness onset: ___/___/_____
10. What symptoms have you experienced?

Symptoms	Yes	No	Symptoms	Yes	No
Fever			Diarrhoea		
Chills			Loss of appetite		
Headache			Muscle/joint pain		
Fatigue			Jaundice		
Rash			Bleeding		
Cough			Fits		
Shortness of breath			Loss of consciousness		

Any other symptoms:

_____

_____

_____

Surveillance officers are assigned to update the linelist to ensure all fields collected through the case questionnaire can be stored in the linelist. The data dictionary is updated as follows:

Figure 11: Updated data dictionary

Variable	Variable type	Variable description	Variable options
Case_ID	Categorical	Unique case identifier	Sequentially assign case number, M1, M2, etc.
Case_classification	Categorical	Case classification status	Possible | Probable | Confirmed | Non-outbreak | Unknown | no_data
Name	Categorical	First name, Last name, 2x2	E.g. Pe Jo for Peter Jones | no_data
Age_years	Numeric	Age in years	E.g. 0 (if < 1 year-old) | 5 | 10 | 21 | Unknown | no_data
Age_months	Numeric	If < 1 year-old (12 months) infant, age in months	E.g. 1 | 7 | 11 | | NA if > 1 year-old | Unknown | no_data
Sex	Categorical	Biological sex	Male | Female | Unknown | no_data
Pregnancy	Categorical	Is the case a pregnant female?	Yes | No | NA, if male| NA, if female infant | Unknown | no_data
Village_name	Categorical	Name of village	E.g. Alpha | Beta | Unknown | no_data
District_name	Categorical	Name of district	E.g. Green Hills | Valley | Unknown | no_data
Occupation	Categorical	Type of occupation	E.g. Road worker | Farmer | Office | School | Unemployed | no_data
Onset_date	Date	Date of sympom onset	dd/mm/yyyy | Unknown | no_data
Fever	Categorical	Did the case experience fever?	Yes | No | Unknown | no_data
Chills	Categorical	Did the case experience chills?	Yes | No | Unknown | no_data
Headache	Categorical	Did the case experience fever?	Yes | No | Unknown | no_data
Water_source	Categorical	Source of household's water	Surface water | Well | Tank | Piped | Unknown | no_data
House_type	Categorical	Type of housing	Traditional | Mixed | Modern | Unknown | no_data
Window_screens	Categorical	Does house have window screens?	Yes | No | Unknown | no_data
Outdoor_latrine	Categorical	Does houseold use an outdoor latrine?	Yes | No | Unknown | no_data
Outdoor_cooking	Categorical	Does household use outdoor cooking facilities?	Yes | No | Unknown | no_data
Mosquito_bites	Categorical	Exposure to mosquito bites in the 14 days before onset date?	Yes | No | Unknown | no_data
LLIN	Categorical	Consistent use of a long-lasting insecticidal bed net?	Yes | No | Unknown | no_data
Repellent	Categorical	Does the case apply mosquito repellent?	Yes | No | Unknown | no_data
Dx_test	Categorical	Did the case have a diagnostic test?	Yes | No | Unknown | no_data
Test_type	Categorical	What type of diagnostic test was performed?	NA, if no test | RDT | thin smear | thick smear | PCR | Unknown | no_data
Parasite	Categorical	What malaria parasite was diagnosed?	falciparum | vivax | ovale | malariae | Unknown | no_data
Treatment	Categorical	What is the case's treatment status?	Complete | Ongoing | Untreated | Unknown | no_data
Outcome	Categorical	What is the case's clinical outcome?	Recovered | Symptomatic | Died | Unknown | LTFU | no_data *LTFU: lost to follow-up

The next step involves doing a **descriptive analysis** of the line listed data, and **interpretation** of your findings.

7

Describe and interpret the data

7.1 Descriptive analysis

You analyse and describe the linelist data to develop a further understanding of how cases are distributed by **person, place** and **time**. After describing the data, you need to interpret it and to generate ideas as to what is happening (hypothesis generation).

You have been analysing the linelist regularly throughout the outbreak. We now move forward in time to late March 2022, approximately ten weeks after the outbreak was first detected. By now, there have been 149 malaria cases detected since the outbreak investigation started.

7.1.1 Person

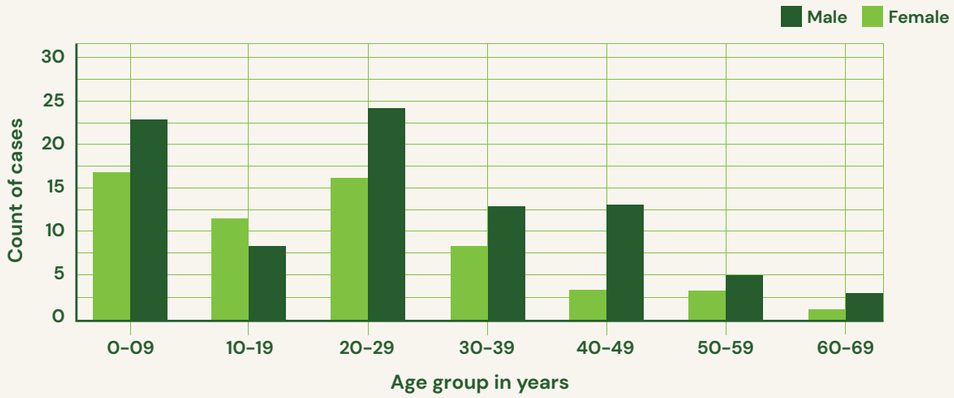
First, you need to begin to understand the characteristics of the people who are sick. You do this by looking for patterns that might provide clues to specific characteristics, activities or exposures that place people at risk of infection with malaria, or may make them more susceptible to severe disease. **Tables** and **column charts** are a useful way to visually summarise case demographic data. Using your Excel linelist, you create some pivot tables to examine the distribution of cases by age group, sex, district, village, symptoms, risk factors for exposure, and other characteristics. You do this regularly as more data are collected and entered into the linelist.

For example, you notice that of the 149 cases, 60% (n=89) were males. The median age of cases was 23 years (range: 2 months to 69 years); however, the majority of cases (100/149; 67%) were people younger than 30 years of age. This is not an unexpected finding in a non-endemic area, because the majority of younger people would not have had any previous exposure or immunity to malaria.

Table 7.1. Distribution of malaria cases in Green Hills and Valley Districts, by age group and sex, Nov 2021 - Mar 2022.

Age group (yrs)	Female	% Female	Male	% Male	Total	% Total
0-9	17	43	23	58	40	27
10-19	12	60	8	40	20	13
20-29	16	40	24	60	40	27
30-39	8	38	13	62	21	14
40-49	3	19	13	81	16	11
50-59	3	38	5	63	8	5
60-69	1	25	3	75	4	3
Total	60	40	89	60	149	100

Figure 12: Malaria outbreak cases, by age group and sex, Green Hills and Valley Districts, Nov 2021 - Mar 2022.



Knowing that infection with the malaria parasite *P. falciparum* can result in severe illness in children, you have a closer look at these data. You notice that 27% (40/149) of all cases were in children under 10 years of age. Of these, 15/40 (38%) were in infants less than 12 months old. Tragically, three out of these 15 infants died, resulting in a high infant case fatality rate of 20%. However, you also notice that there is missing data here: 4/15 (27%) of the infant cases have no data on their clinical outcome recorded, meaning the infant case fatality rate may actually be even higher than what the data currently indicates. The investigation team will need to do additional work to follow up on these infant cases!

Table 7.2: Clinical outcome of malaria cases in infants (under 12 months of age) in Green Hills and Valley Districts, Nov 2021 - Mar 2022.

Outcome	n	%
Recovered	7	47
No data	4	27
Died	3	20
Symptomatic	1	7
Total	15	100

You decide to further investigate cases in the other over-represented age group, namely those cases 20-29 years of age. You notice that of the 40 cases in this age group, 63% (n=25) reported farming as their occupation, whereas 8/40 (20%) reported being road construction workers. The distribution of occupation in this age group may not be unusual considering the region where these cases have been reported. The results may also suggest that a majority of these cases are likely to spend a lot of their time outdoors, which may increase their exposure to mosquito bites.

Table 7.3: Malaria cases in 20-29 year old age group, by occupation, Green Hills and Valley Districts, Nov 2021 - Mar 2022.

Occupation	n	%
Farmer	25	63
Road worker	8	20
Office worker	3	8
Mechanic	1	3
Taxi driver	1	3
Home	1	3
No data	1	3
Total	40	100

7.1.2 Place

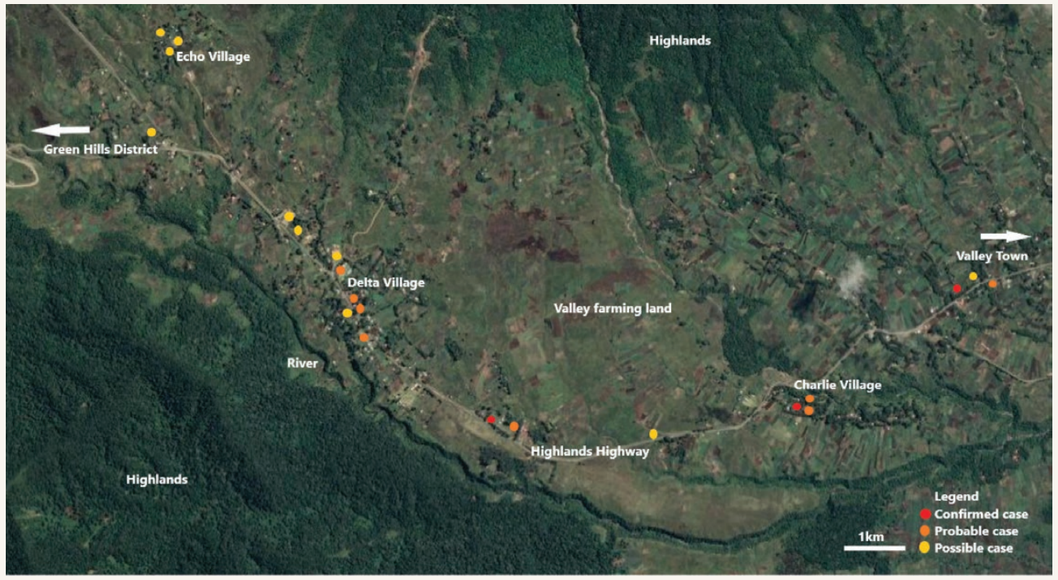
Because malaria is a vector-borne disease, using maps to visually display case locations or other landscape features (e.g. water sources) may provide useful clues about transmission patterns, or risk factors for exposure. Google Maps is a useful resource for this purpose (2). You decide to create a map to display the location of the first cases meeting the case definition with the affected area around Nurse Dorothy's community health post. Nurse Dorothy knows the community well, and is able to assist you by providing a hand-drawn map to pinpoint the location of cases houses. You notice that most of the cases are clustered close to each other, and in a lower-lying area near the road and river, which runs between the high mountains surrounding the villages served by the community health post.

You also notice the nearby river and ponds of free-standing water in between the areas of cropland, near the villages. You're concerned these may be areas where mosquitoes could be breeding. If these mosquitoes are biting infected people in the area, this may result in further transmission of malaria if case treatment and environmental control measures are not implemented.

Figure 13: Distribution of malaria cases in the area serviced by Nurse Dorothy's Community Health Post.

Meanwhile, your colleague Peter has started mapping cases in Valley District, along the Highlands Highway up the valley towards Green Hills District. Again, it appears that a similar pattern is emerging, namely that cases are distributed along the road leading up the valley. You start to formulate a hypothesis, that malaria may have been spreading in the highlands region due to the unusually hot and humid wet season which has resulted in plentiful mosquitoes, combined with the movement of infected people along the Highlands Highway.

Figure 14: Distribution of malaria cases in the farming region of Valley District.



7.1.3 Time

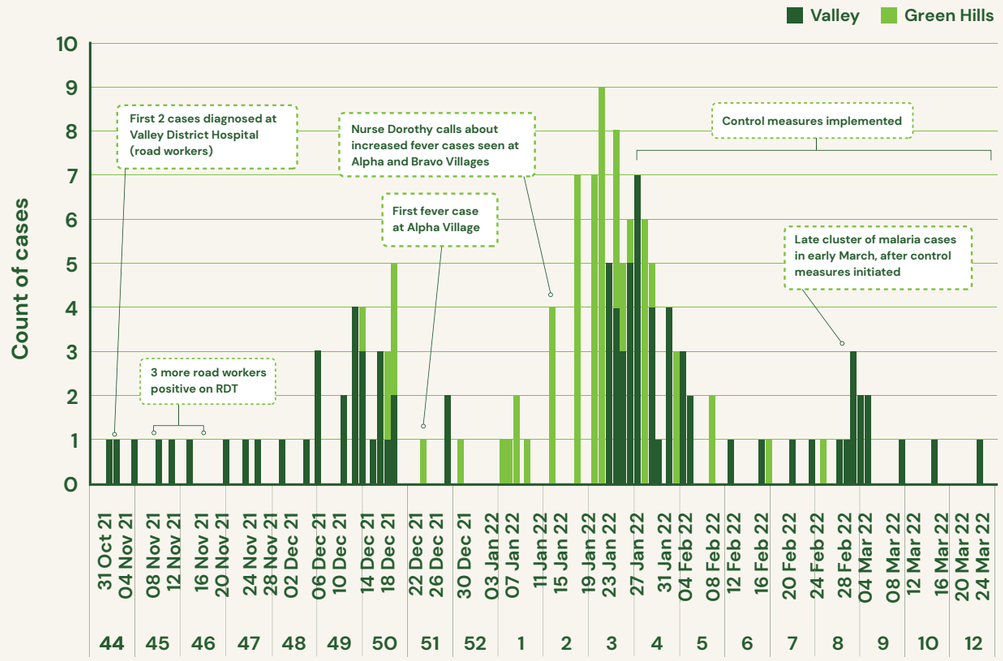
An **epidemiological curve (epicurve)** displays the count and distribution of cases over time, by reported symptom onset date. You decide to generate two epicurves, to help further develop your ideas about what has been happening (hypothesis generation).

You first create an epicurve of cases by affected district. You note a few interesting findings. Firstly, you can see that the majority of cases (104/149; 70%) were from Valley District, and that the outbreak appears to have persisted longer in this district after malaria control measures were implemented in late January. This makes sense, considering that Valley District has a far larger population than Green Hills District, and that control efforts were more difficult to implement in a large farming area with a busy highway transporting people, goods, and livestock. There were also several temporary construction camps along the sections of the road under construction.

Secondly, you notice that there appears to have been fewer cases with a reported symptom onset date between late December and early January, compared to the previous two or three weeks. You wonder if this is a true finding, and if so, why that could be?

Finally, you also notice that there was a later, smaller cluster of cases in Valley District in early March, several weeks after malaria control measures were implemented in late January. Again, you wonder if there is a specific reason. You wonder if there was continued transmission in a specific village, or some other explanation? You decide to look at those cases more closely in search of answers.

Figure 15: Epidemiological curve of malaria outbreak by symptom onset date and district, Valley and Green Hills Districts, Nov 2021 - Mar 2022.

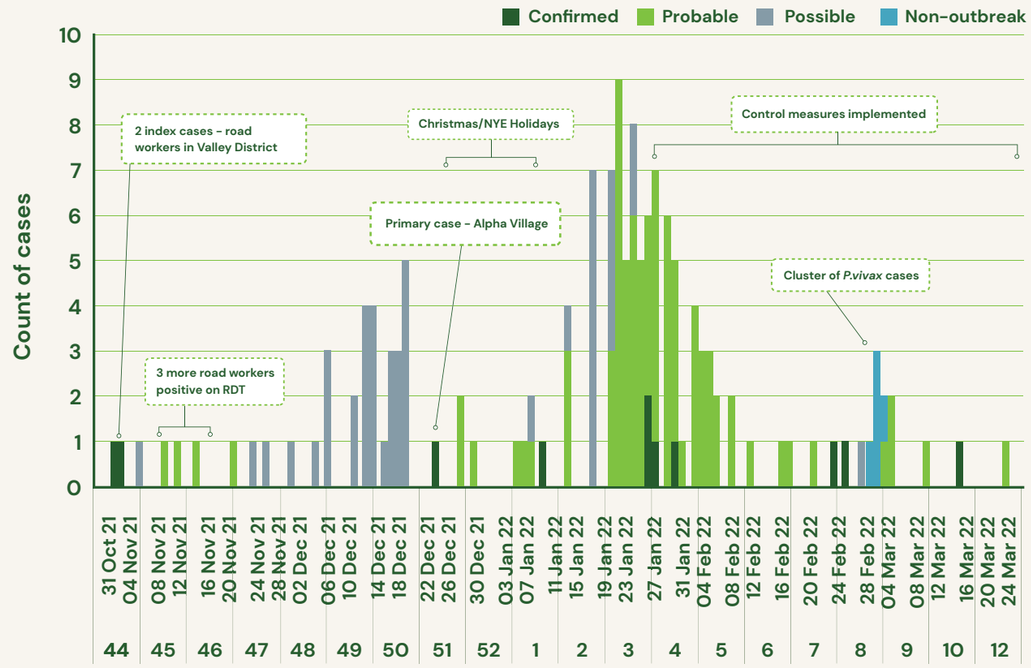


Your second epicurve shows the outbreak by case classification status, based on the case definition that was developed. This helps to make the picture of what happened a bit clearer. For example, you notice that the majority (n=86; 58%) of cases were classified as 'probable', meaning they received a positive RDT result confirming malaria infection. This is an encouraging finding, because it suggests that the outbreak investigation team did a good job making sure that RDTs were distributed and used by surveillance and case management officers out in the affected areas.

Secondly, you realise that the fewer cases with a reported symptom onset date during late December and early January may not show the full picture of what happened, because this was also the Christmas and New Year's Holiday period. It's likely that some cases may have been missed, e.g. because they were visiting friends or relatives in other districts. Some people may have felt unwell, but chose to delay seeking healthcare until after the Christmas period was over, or because some health facilities may have been closed, except for serious emergencies. It may also be that the increased movement of people and goods being transported along the Highlands Highway during that period may have further spread malaria. This could have led to a further increase in transmission rates and case numbers in January and February, had it not been for the control measures that were thankfully implemented from late January in response to the outbreak.

Finally, you notice that the cluster of cases in early March included five cases of *P. vivax*. Upon further investigation, you learn that these five cases were diagnosed at Valley District Hospital. They were all males, specifically road workers who had recently arrived from another island where they shared the same house, to start their work shifts on the highway reconstruction project. Knowing that the average **incubation period** (the time between infection and onset of illness) for *P. vivax* can be several weeks, you conclude that they most likely did not acquire their *P. vivax* infections in Valley District, and therefore do not strictly form part of this outbreak. Because these cases were initially entered into the linelist as 'probable' cases and only later confirmed as *P. vivax* infections, that explains why they are reflected in the epicurve as 'non-outbreak' cases.

Figure 16: Epidemiological curve of malaria outbreak by symptom onset date and case classification status, Valley and Green Hills, Nov 2021 - Mar 2022



7.2 Analyse environmental exposures

Returning to the pivot tables you created from the Excel linelist, you start to notice a pattern of frequently reported factors which may increase the risk of contracting malaria in the affected outbreak districts.

For example, you note that of the 97 'probable' and 'confirmed' cases for whom interview data were available:

- The majority (92/97; 95%) reported living in mixed or traditional-style housing, as opposed to modern homes. Only 8/97 (8%) of cases reported having window or door screens to protect against mosquito entry into their home.
- The majority of cases reported having wells (54/97; 56%) or surface water sources (27/97; 28%) as their primary source of water, as opposed to closed tanks or a piped water supply.
- The majority of interviewed cases (86/97; 89%) reported cooking food outdoors; and
- The majority of cases (70/97; 72%) did not report consistent use of a long-lasting insecticidal bed net (LLIN).

7.3 Generate outbreak hypotheses

Based on the information systematically collected by the team during the outbreak investigation, you determine that the following factors all likely contributed to the outbreak of *P. falciparum* malaria in Green Hills and Valley Districts which occurred between the months of November 2021 and March 2022:

- Above-average rainfall and humidity resulted in an unusual increase in the number, activity and survival of the malaria vector species, the *Anopheles* mosquito in the Highlands region, which is usually cooler and not considered a malaria-endemic area.
- In addition to the region's younger population age structure, a lack of underlying population immunity to *P. falciparum* may also explain the higher proportion of symptomatic infections seen in younger age groups in the outbreak districts, compared to older age groups.
- The same wet and humid conditions led to higher rates of endemic malaria transmission in the lower-lying provincial coastal areas and in other low-lying islands. Combined with the movement of infected people into the Highlands region, e.g. for work on the highway reconstruction project, or traveling home during the Christmas and New Year's holiday period, these factors created the right conditions for the introduction of *P. falciparum* malaria into the outbreak districts.

The following population characteristics likely also contributed to the outbreak:

- Standing water near homes, e.g. buckets collected from nearby wells or open water sources which provide mosquito breeding areas;
- Low uptake of mosquito prevention measures, specifically the consistent use of long-lasting insecticidal bed nets (LLIN);
- The high number of mixed or traditional-type housing without mosquito screens; and
- Outdoor activities at night, e.g. outdoor cooking, especially at dusk.

Based on previous knowledge of malaria epidemiology and these hypotheses, the outbreak team had thankfully implemented various outbreak **control measures**, including a risk communications plan to share important public health messages to the communities at most at risk.

Implement control measures

Malaria prevention and control methods were intensified as soon as the outbreak case definition was developed and the outbreak team activated. Control methods comprised of several components, as outlined below. Information was constantly shared with the vector control and risk communications teams, through the SitReps and regular Outbreak Team meetings.

Vector control

The vector control team used an integrated mosquito management (IMM) approach to control mosquitoes, by focusing on the various stages of the mosquito life cycle, namely: removing places where mosquitoes lay eggs, controlling larvae and pupae, and killing adult mosquitoes (3). Control measures included the following:

- **Indoor residual spraying (IRS)** involves coating the surfaces of a house with a long-lasting residual insecticide, which kills mosquitoes when they come to rest on an indoor surface after feeding. This prevents transmission of infection to other persons (4).
- Vector control officers engaged in **community consultation to identify mosquito breeding areas** near villages, and to help the community identify and remove standing water sources in or near villages or homes.
- Application of **insecticides** to kill adult mosquitoes (using products called **adulticides**), by using backpack sprays in villages and truck spraying along the Highlands Highway and secondary roads leading into the affected villages.
- Application of insecticides to standing surface water sources near affected villages or homes, to kill mosquito larvae and pupae in mosquitoes breeding locations (using products called **larvicides**).

Surveillance

- Initially, **active surveillance** focused on case detection, which is defined as *"the detection by health workers of malaria infections at community and household level in population groups that are considered to be at high risk of infection" (5).*
- By mid-February, the incidence of new outbreak cases was slowing down, the strategy shifted to **passive surveillance**, namely receiving reports of additional malaria cases.

Testing

The outbreak team's logistics/finance, surveillance, laboratory and case management teams collaborated to ensure access to and use of rapid diagnostic tests (RDT) for malaria diagnosis. Training on RDT use was provided for primary healthcare staff, where required.

Treatment

The outbreak team's logistics/finance, and case management teams collaborated to ensure the widespread availability and use of anti-malaria medications, e.g. artemisinin-based combination therapy (ACT), in line with the consolidated WHO Malaria Treatment Guidelines (6).

Additional training and support on malaria treatment protocols were provided to primary healthcare staff, where required.

Preventive measures

- Ensuring access to, and consistent use of **long-lasting insecticidal bed nets (LLIN)** in communities at risk.
- The outbreak team's logistics/finance and communications teams collaborated to implement the **risk communication plan** to raise public awareness and to provide key information to communities at risk on malaria prevention and control.
- The strategy also including encouraging people experiencing symptoms to come forward for rapid diagnostic testing and early treatment.

9

Communicate findings

9.1 Stakeholder communication

The outbreak investigation team developed a weekly 2-page **Situation Report (SitRep)** for communicating outbreak response updates to the Ministry of Health Senior Management, and other relevant Ministries (e.g. Department of Environment, Roads and Transport).

The SitRep always included the following information:

- Date/Time;
- Current outbreak description;
- Key results of descriptive analyses;
- Laboratory results and findings;
- Response activities underway or planned;
- Resource needs; and
- Any other key information to be shared.

You also developed a formal **outbreak investigation report**, which provided an accurate, concise scientific overview of the key findings, and documented all steps undertaken during the course of the outbreak investigation and the response. Importantly, it also included **key lessons learnt** and **recommendations** to prevent or better manage similar outbreaks in future.

The outline of the outbreak investigation report included the following sections (7):

Background

- Nature of the problem and public health importance
- Contacts in the field and investigation team
- Pertinent information and situation
- Objectives of the investigation

Methods

- Outbreak case definition
- Case finding methods
- Laboratory methods
- Environmental investigation

Results

- Descriptive epidemiology
- Laboratory findings
- Environmental findings

Conclusion

Recommendations

- Signatures of principal investigator and supervisors

9.2 Risk communication

The risk communications team successfully implemented their communications plan, which included a public service announcement on the local radio station, sharing malaria prevention messages via SMS and village to village consultation with community leaders, and using posters and pamphlets in areas where people congregate such as marketplaces, public transport stations and church services. Importantly, these messages contain key information on malaria prevention and encourages people experiencing symptoms to come forward for testing and early treatment.

An example of the key malaria prevention messages for community health workers is provided below (Figure 17). This information was shared with Nurse Dorothy and her colleagues, then translated into the local language. The posters and pamphlets based on these key messages included plenty of pictures to make it easily understandable for those people who cannot read.

Figure 17: Depiction of community engagement for risk communication

10

Conclusion

By late-April, there were no new reported malaria cases in the affected Green Hills and Valley districts for a period of 28 days (double the maximum 14-day incubation period for *P. falciparum* malaria). Based on this encouraging finding, the team decides to declare the outbreak over, and to stand-down the public health response. As a final step, the Incident Manager decides to debrief the outbreak investigation team by holding an **After-Action Review (AAR)**. This provides the team members with a valuable opportunity to reflect on their individual experiences, to share lessons learnt, talk about what worked well or not so well, and to be thankful for saving countless lives through their team effort and hard work.

Figure 17: Key malaria prevention messages for community health workers.

Stop Malaria in the Highlands!

Malaria is a dangerous illness spread by mosquitoes. Always practice the 1 B and 5 D's of malaria prevention to keep you and your family safe, and our Highlands region malaria-free. The most important single measure to prevent malaria, is to prevent mosquito bites.

B for BED NETS

Always sleep under long-lasting insecticidal bed nets to prevent mosquito bites. This is especially important for at-risk groups such as young children, pregnant women, the elderly, or persons with poor immune systems or suffering from other chronic illnesses. It is very important that anyone who has an infection passed on by mosquitoes sleeps under a bed net until they are treated and recovered – to stop new mosquitoes biting them and passing the disease on to other people.

D for DOORS

Doors and window screens can help prevent mosquitoes from entering the home to bite people. Remember to always keep door and window screens closed to keep mosquitoes out, particularly during early evening times. Where available, using fans indoors can also help prevent mosquito bites by creating a cool, unwelcoming environment for mosquitoes.

D for DRESS

When doing outdoor activities at dawn, dusk or during the night, e.g. collecting water, visiting the bathroom or cooking dinner, it's recommended to wear long-sleeved clothes and closed shoes to help prevent mosquito bites.

D for DRAIN

Get rid of mosquito breeding sites. Mosquito breeding sites are any containers that water can sit in for more than a couple of days. This includes: tyres, dishes left outdoors, coconut shells, buckets and drums used to collect rainwater, seashells and roof gutters. Some mosquitoes are found inside houses so it is important to remove or cover any water sources such as pot plant saucers or water tanks.

D for DEET

DEET-containing products, or other insect repellent sprays, and burning mosquito coils can help prevent mosquito bites.

D for DOCTORS

Consult a healthcare worker if you or someone you know develops the symptoms of malaria (e.g. fever, chills, body aches, or headaches). A rapid test can quickly tell if you have malaria. Malaria is a curable disease. Early treatment is important to prevent severe illness and death.

11 References and additional resources

This evidence-based case study was developed through a review of the scientific literature and publications produced by global public health agencies including the World Health Organization (WHO) and the United States and European Centres for Disease Control and Prevention (8-16).

For additional information, refer to the publicly-available resources and references provided below:

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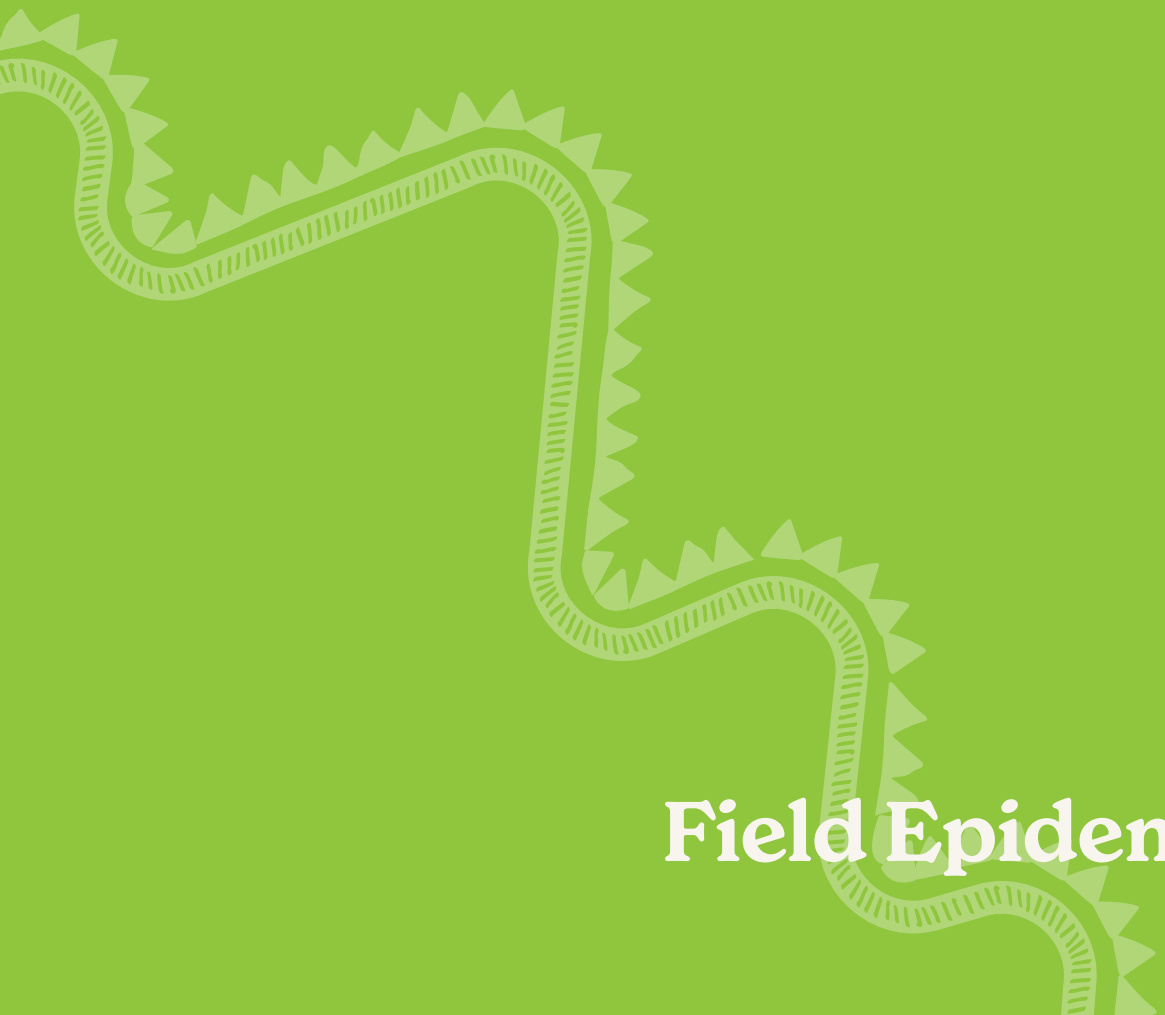
CASE STUDY

OUTBREAK INVESTIGATION IN THE FIELD



Field Epidemiology
IN ACTION