# BIOPHYSICAL INTERACTIONS: MALARIA

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## Syllabus link

This article provides a background for teachers to approach the Preliminary Stage 6 Geography unit of 'Biophysical Interactions.' This unit requires students to look at the four spheres we live and operate in, and their interactions with each other and ourselves. What this paper aims to achieve is to provide a case study that satisfies the syllabus dot-point of investigating an issue and showing how it can be sustainably managed. Malaria is a natural hazard that highlights the interactions between at least two of the four biophysical components: the biosphere and the hydrosphere. This paper satisfies all requirements within its relevant syllabus dot-point, looking at its spatial distribution and cause, interactions of the components of the biophysical environment, responses to the hazard, how climate change is affecting it, and what strategies can be used to mitigate it.

A case study investigating ONE issue in ONE of the biophysical components, to illustrate how an understanding of biophysical processes contributes to sustainable management in the environment. The investigation will include:

- identification and explanation of the key biophysical processes which relate to the issue
- scale of operation
- interactions with other components of the biophysical environment
- the sensitivity of the biophysical environment to change
- the importance of understanding key biophysical processes for effective management

## Introduction

The United Nations Office for Disaster Risk Reduction defines a 'hazard' as "a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage" (n.d.). It is possible, therefore, to make a distinction between extreme events in nature that are not environmental hazards because people and property are not at risk, and environmental hazards in which people and property are at risk (Nagle 1998). The natural event can only be a hazard when there is a degree of community vulnerability. To be vulnerable, one must have a high level of susceptibility (the fact of being exposed) and a low level of resilience (the capacity to adapt and recover). This paper will examine malaria as a natural hazard, how it impacts on humans and in turn, how humans impact on the hazard. It will also discuss suitable management strategies, and offer some practical teaching strategies.

## Malaria as a natural hazard

Malaria is caused by the invasion of the human bloodstream by a protozoan parasite of the Plasmodium genus. There are four species that currently infect humans: Plasmodium malariae, Plasmodium ovale, Plasmodium virax and Plasmodium falciparum (Packard 2007). For malaria, a vector-borne disease (a disease spread by a living organism) to be transmitted, a malaria parasite must first be ingested by a female Anopheles mosquito, undergo sexual reproduction within it and then be passed to a second human through the bite of the infected mosquito (Packard 2007). The parasite must sexually reproduce within the mosquito before it can be passed on to another human (this takes roughly 14 days). The fact that the average female Anopheles mosquito survives for roughly 10 to 21 days means that if the mosquito ingests the parasite close to the end of its life cycle, the parasite dies with the mosquito and can no longer infect a human (Packard 2007). Figure 1 below illustrates the malarial life cycle.

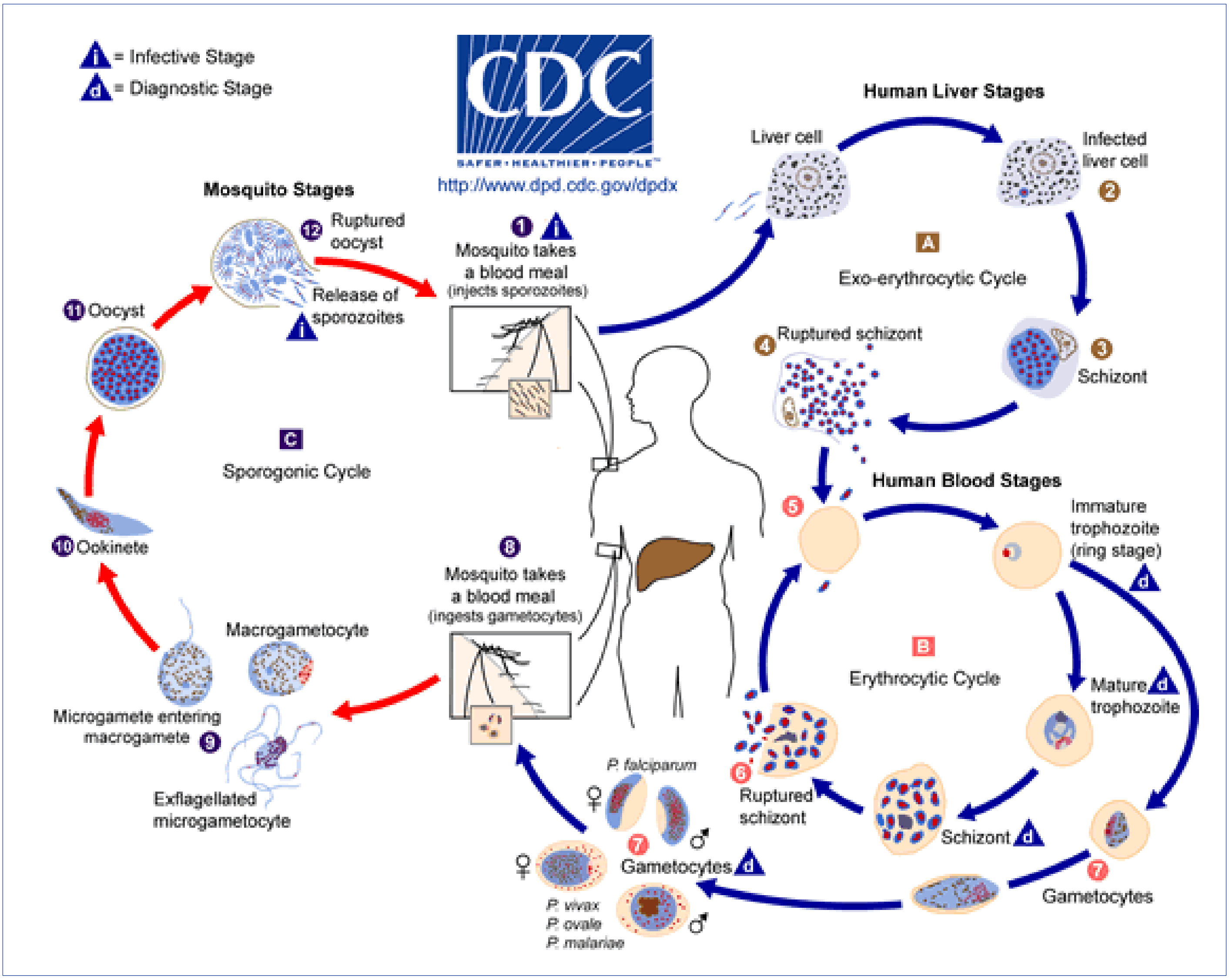


*Figure 1: Malarial Life Cycle (Centres for Disease Control and Prevention 2010) – http://www.cdc.gov/malaria/about/biology/*

Once bitten by an infected mosquito, sporozoites enter the host's liver where they undergo a cellular division into numerous merozoites cells. When the merozoites mature, they enter into the human bloodstream and invade the circulating red blood cells. The parasite grows within the blood cell, eventually producing daughter cells, which burst from the blood cell and invade other red blood cells, repeating the reproduction cycle. Gametocytes (male and female forms of the merozoite cells) circulate in the blood stream (but not inside red blood cells). The female Anopheles mosquito will ingest these gametocytes during their blood meals, which completes the reproduction stage of the parasite and produce fresh sporozoites, which enter the salivary glands of the mosquito. When the mosquito bites a human, the saliva infects the human, and the malaria life cycle recommences (Packard 2007).

According to Nagle (1998), the conditions for malaria to develop are still water in which the mosquitoes lay their eggs; and temperatures greater than 16°C for the parasite to develop inside the mosquito, but lower than 32°C, as a large number of the parasites die. Figure 2 below illustrates the geographical distribution of malaria.

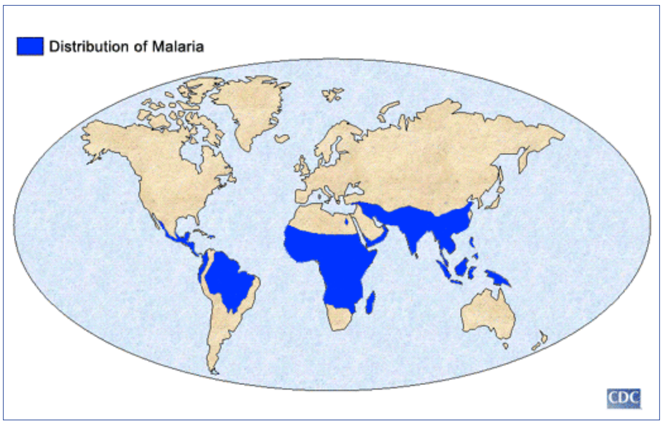


*Figure 2: Geographical Distribution of Malaria (Centres for Disease Control and Prevention 2010) – http://www.cdc.gov/malaria/about/distribution.html*

*Natural wetlands of northern Vietnam. Source: https://www.flickr.com/photos/dfataustralianaid/10695647683/in/photostream/*

## Human impacts on the hazard

Malaria – although occurring naturally within the lifecycle of the mosquito – can be propagated by human actions and activities. Quite often, these human activities do not take into account any impacts they could have on the spread of malaria. Nagle (1998) states that the disease is affecting new victims because of increased trade and travel transporting the parasite across borders to areas which have never had the disease and infecting people who do not have immunity, and the expansion of agricultural schemes which incorporate irrigation techniques which promote the stagnation of water. Packard (2007) expands on this by offering examples of such cases in which the malaria parasite has been propagated by human activities. Urbanisation (especially in the tropics) has played a vital role, with mosquitoes being able to breed in rain barrels, drainage ditches, discarded canisters and discarded tyres taking advantage of poorly housed, highly concentrated populations. Packard (2007) also makes mention of specific human projects which have contributed to the spread of malaria. Poorly farmed cotton plantations in the United States of America and rice farmers in Northern Italy were particularly at risk due to the irrigation systems put in place.

Another way in which humans are impacting on malaria is through a very gradual climatic transition. Anthropogenic climate change is causing the heating of areas that were once too cold for the malaria parasite to survive. Warmer weather has not only quickened the pace of mosquito-borne infections such as malaria, but it has also expanded their 'hunting grounds' (Nikiforuk 2007). As rainfall increases, the mosquitoes that carry the parasite will spread and lengthen the malarial season, thus leading to the proliferation of the disease (Flannery 2008). Flannery (2008) states that due to the globe warming, even by a degree or two, the incidence of humans exposed to the malaria parasite will rise from 45% to 60%.

## Impact of the hazard on humans

There are two forms of transmission: 'unstable' is where transmission rates are low and immunity does not develop, meaning epidemics and deaths occur in all age groups; 'stable' is where children are repeatedly infected, with those surviving acquiring immunity, meaning that they are less likely to die from the disease as adults, however, may still suffer from mild symptoms (ed. Lomborg 2006). Honigsbaum (2002) claims that it is also possible for people to have a natural immunity to malaria through genetic traits that have evolved in response to long exposure to the disease. Malaria is a cause of anaemia, contributes to low birth weight when contracted during pregnancy and is also believed to have a significant negative impact on intellectual development (ed. Lomborg 2006).

The symptoms associated with malaria, and affecting the physical health of the infected person are chills, followed by a dramatic rise in temperature. Soon after, the person will have a raging thirst and headache, followed by delirium. When the headache and temperature subside, there will then be a stage of profuse perspiration. This cycle of chills to perspiration continues as more and more red blood cells are infected by the parasite. This cycle does in many cases result in the death of the person (Honigsbaum 2002). It is estimated that approximately 300–500 million people suffer from malaria each year, with almost 2 million dying (mostly children under 5 years of age). Sub-Saharan Africa accounts for 90% of these cases (Garg et al. 2009). The aspect of health is not the only impact that the malaria hazard has on humans.

The impact of the hazard on the economy must also be taken into account. Between 1965 and 1990, countries with a large percentage of the population infected with malaria grew by 1.3% less per year than unaffected countries. This results in 33% lower income. It is also claimed that a 10% reduction in malaria would bring about a 0.3% increase in annual GDP growth (ed. Lomborg 2002). The impacts of malaria fall heaviest on the poor, with treatments representing anywhere from 7% to 18% of income (ed. Lomborg 2002). Malaria also impacts on the economy through absenteeism from school and work and reduces productivity. According to Sachs (2005), there is a direct correlation between poverty and malaria. This means that the regions most affected by malaria not only suffer from widespread health implications, but also economic ones.

Community vulnerability in the case of malaria can be considered in two streams: susceptibility and resilience. The susceptibility (the fact of being exposed) of people who are in malaria infected areas is quite high, especially as most of these areas lack strong economic backgrounds to provide people with basic health services or gain access to simple preventative items (such as anti-malarial bed nets). Malnourished people (meaning, most regions in Africa, Asia and Northern South America) are also at higher risk of being infected. Therefore, there is a high level of susceptibility as people come into direct contact with the disease-carrying mosquito and live amongst the breeding sites.

The resilience (the capacity to adapt and recover) of people is also quite low as most people who are infected include young children (having weak immune systems) and the poor (as they lack the resources to access suitable treatment or migrate to non-infected regions). The working days missed and the absences from school cause a reduction in production and

*Mosquito, Anopheles minimus. Source: https://upload.wikimedia.org/wikipedia/commons/d/da/Anopheles_minimus.jpg*

income. Thus, the ability to recover from the illness is also economic. It may be difficult to recover from this loss in income, making it harder for the household to purchase vital necessities. It is difficult to adapt without significant financial backing, and only with a suitable management strategy can both the susceptibility and resilience be improved, thus reducing the vulnerability. Therefore, malaria poses both a natural risk and causes the community to be vulnerable as the people in the regions affected have both a high level of susceptibility and a low level of resilience.

## Current and future management strategies

While malaria can be treated, such treatment can be costly, time consuming, and not fully effective. This, however, should not be an excuse for inaction. While there are treatments for malaria, namely Quinine (Honigsbaum 2002), there is no known fully effective vaccine (one which counters all stages of the parasite cycle and strains). The most effective way to counter malaria is to prevent it from happening, rather than to cure it (a form of loss avoidance). This can be done in a number of ways.

The use of insecticide treated bed nets (ITNs) is a viable option, as it stops the spread of malaria when people are most vulnerable. The most efficient way to rapidly increase ITN coverage is through a free distribution campaign (Yukich et al. 2008). According to Sachs (2008), it is possible to provide ITNs in Africa that last for up to five years at close to minimal costs. With new technologies increasing the development of better ITNs, a net costs $5 and on average, three nets are required to protect five people in the household. With three hundred million sleeping sites to be covered in Africa, a program of ITN coverage that lasts for five years will cost approximately $1.5 billion (the same as one day's budget for the 'Pentagon') (Sachs 2008). In order to

*Left: Angolan children with bednets. Source: https://upload.wikimedia.org/wikipedia/commons/5/54/Angolan_children_with_bednets_%285686769577%29.jpg*

*Stagnating floodwater Manila, Philippines 2012 Source:* https://www.flickr.com/photos/dfataustralianaid/10695594406/in/photostream/

provide for all the measures needed to control malaria in all of sub-Saharan Africa (ITNs, medicines, community health workers, indoor residual spraying and education) would require around $3 billion (Sachs 2008).

Another option available for reducing the malaria risk is the use of DDT (Sachs 2005). It will not eliminate transmission entirely; however, when sprayed in mosquito breeding sites, it can significantly reduce the mosquito population. When this is used in conjunction with medicines, ITNs and artemisinin therapies, it can significantly reduce the burden of malaria (Sachs 2005). Honigsbaum (2002) also makes mention that effective ways of preventing malaria is through the draining of swamps and marshes and filling in drainage areas which are open to the surface. The removal of stagnant water sources means that the mosquito no longer has a place to breed.

The use of ITNs is the most effective way of controlling the risk of malaria, and is vital to lower the susceptibility of people in the malaria-affected regions of the world. When this is coupled with effective campaigns to prevent it from spreading through chemicals and supported with medicines to alleviate symptoms and prevent deaths, malaria can be effectively and efficiently controlled. Vaccine development has been occurring for years; however, they can be far too costly for those living in the malaria-affected regions. New vaccines are also constantly being researched and developed. A total of 2007 publications scattered over 352 journal titles originating from 40 different countries were published on the topic of malaria vaccine (Garg et al. 2009).

Management strategies for malaria include: the use of highly effective ITNs, indoor residual spraying, the use of chemicals to control mosquito breeding sites, medical treatments, the removal of stagnant water sources and suitable education. It is impossible to alter the weather conditions in the regions affected by malaria; therefore, it is vital to take those preventative steps to alleviate the vulnerability in some way. These management strategies can occur at any time along the hazard management timeline, and are critical to controlling the malaria risk.


*2011 Malaria Survey, Solomon Islands. Source:* https://www.flickr.com/photos/dfataustralianaid/10695013835/in/photostream/

*Mosquito fogging. Source: https://upload.wikimedia.org/wikipedia/commons/9/9a/Mosquito_fogging.jpg*

## Conclusion

Malaria is a natural hazard as it poses a direct threat to communities, leaving them vulnerable in terms of susceptibility and resilience. There are, however, suitable management options, which can, and must be utilised in order for the vulnerability to be reduced, and thus reduce the risk posed by malaria. In order for these strategies to be properly implemented, a global campaign (such as The Global Fund to Fight AIDS, TB and Malaria) is necessary to bring to light the issues and options available to rid the world of malaria (as was done in Western Europe and North America).

## Suggested Teaching Strategies

Mapping skills are, first and foremost, the most present when dealing with malaria as a hazard.

- Latitude and Longitude: students can identify the latitudes that malaria has 'traditionally' been located in (as derived from Figure 2 above), and make predictions about how climate change will affect its spatial distribution.
- Choropleth mapping: students can construct choropleth maps illustrating the distribution of malaria within a given area.
- The use of photographs that show changes in landscapes due to climate change can also be used, leading to higher-order extension work, such as writing a persuasive text to world leaders calling for action on the underlying causes of malaria.
- There is also an opportunity to integrate the Problem-Based Learning, asking students to work either collaboratively or individually to mitigate malaria as a hazard.

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