Module 8: Vector-borne diseases & climate change

In Module 8 we're going to look at vector-borne diseases and how these are likely to be affected by climate change – a really important issue for health management.

Key messages in Module 8

- Climate change could affect vector-borne disease (VBD) in humans
- Climate change affects vector-borne diseases through several mechanisms
- Impacts will vary from region to region
- Current evidence suggests impacts on some diseases may already be occurring
- Impacts may include unanticipated emergence of new pathogens

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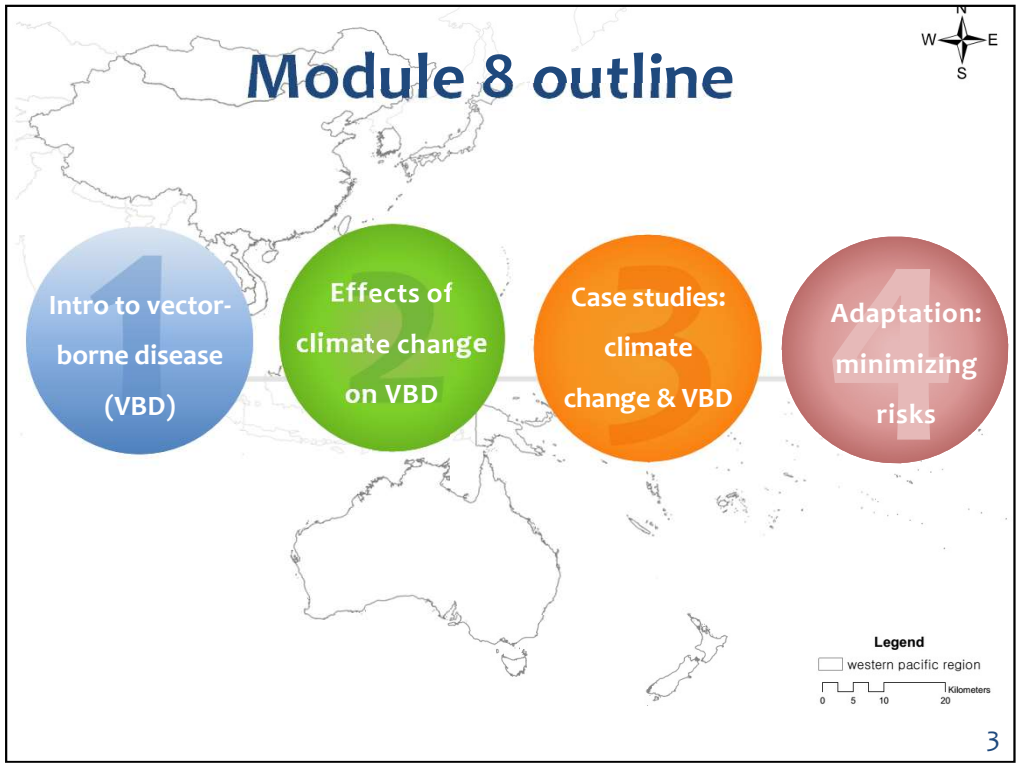
Key messages we'll cover in Module 8 are:

• It is likely that climate change will affect the distribution and incidence of VBD globally
• impacts will vary from region to region
• Current evidence uncovered to date suggests that impacts on some diseases may already be occurring

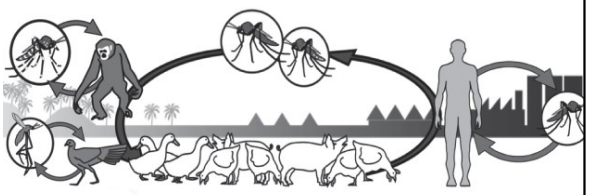
In addition:
• Some of the potential impacts of climate change may include the unanticipated emergence of new pathogens.

Recommended further reading: 2007 IPCC report: The Physical Science Basis, FAQ 3.1 page 103 and FAQ 3.2 page 105



Here's what we'll cover in Module 8:

1. Vector-borne disease (VBD) introduction
2. Effects of climate change on VBD
3. Some case studies of climate change effects on VBD
4. Potential for adaptation to minimize health risks and impacts



Introduction to vector-borne disease (VBD)

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Let's start by looking at a general introduction to vector-borne diseases.

What is vector-borne disease?

Diseases that are spread by arthropod or small animal vectors.

Vectors act as the main mode of transmission of infection from one host to another, & as such form an essential stage in the transmission cycle.

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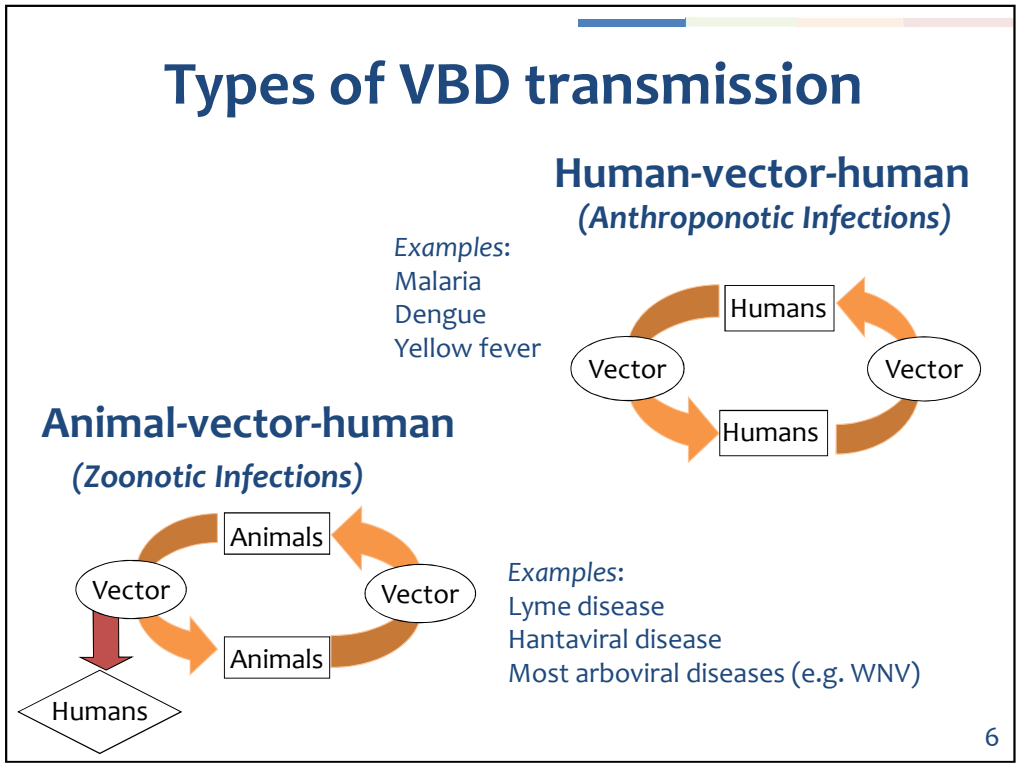
VBDs are diseases that are spread by arthropod or small animal vectors.

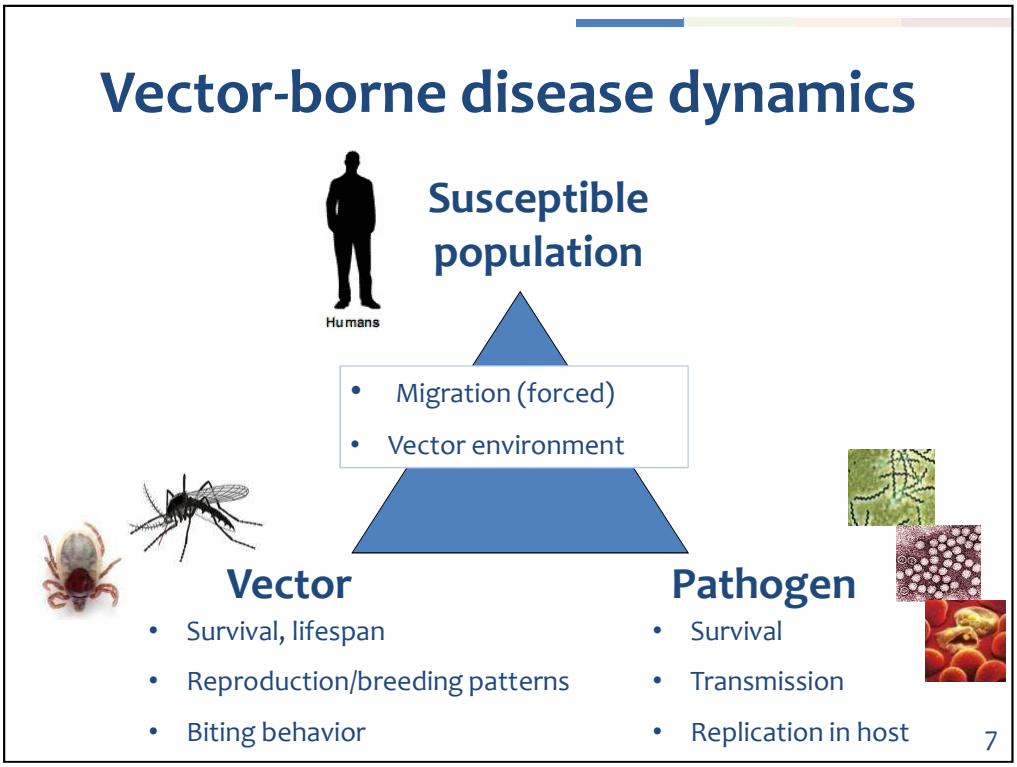
Vectors act as the main mode of transmission of infection from one host to another and as such form an essential stage in the transmission cycle.



Two main types of VBD transmission exist:

1. Anthroponotic infections – or human-vector-human transmissions, where humans are the only reservoir of the disease
2. Zoonotic infections – or animal-vector-human transmission, where animals are the main reservoir of the disease and humans are considered secondary or spillover hosts and do not generally contribute to the disease transmission cycle as their levels of circulating pathogen are often too low to help maintain transmission.

The type of transmission of a VBD has implications for control strategies. Anthroponotic infections can theoretically be eradicated if all human cases of the disease can be treated, whereas zoonotic diseases are much more difficult to control since all animal reservoirs of the disease would need to be treated.



There are 3 crucial elements which must co-exist for the occurrence of VBD:

1. The susceptible population
2. The vector (most often arthropods), and
3. The disease pathogen (e.g., bacteria, virus, parasite).

In areas where VBD most frequently occurs, conditions must be suitable for vectors and pathogens, which implies physiologically suitable conditions for vector, host, and pathogen survival and reproduction/replication.

There are a number of areas in the world where conditions may be suitable for all three components; however, other factors have acted to prevent or eradicate disease transmission in these areas, perhaps as a result of improved health care services or vector control measures.

Global climate change is likely to affect all 3 of these components both directly and indirectly. As an example of direct effects: Arthropods are highly sensitive to changes in temperature and precipitation as they cannot regulate their own internal temperatures and are therefore critically dependent on climate for survival and development (Githeko et al., 2000). Changes in climate may accelerate the development time of some arthropod species, for example.

Similarly, many pathogens are climate sensitive as well, and changes in climate could result in increased reproduction rates of some pathogens.

Some example of indirect effects might include: Changes in livelihood conditions due to climate change, which could affect nutritional status of individuals, thereby potentially increasing susceptibility to disease.

The next section will cover indirect and direct effects of climate change on human health in more detail.

Vector-borne diseases of concern

Protozoan

Disease	Pathogen	Vector	Transmission
Malaria	*Plasmodium falciparum, vivax, ovale, malariae*	***Anopheles* spp. Mosquitoes**	**Anthroponotic**
Leishmaniasis*	*Leishmania* spp.	***Lutzomyia* & *Phlebotomus* spp. Sandflies**	**Zoonotic**
Trypanosomiasis *	*Trypanosoma brucei gambiense, rhodesiense*	***Glossina* spp. (tsetse fly)**	**Zoonotic**
Chagas disease*	*Trypanosoma cruzi*	***Triatomine* spp.**	**Zoonotic**

* WHO neglected tropical disease

Source: Hill et al. (2005) 8

Which vector-borne diseases are of most concern?

There are many VBDs of concern, especially in developing countries, a number of which are on the WHO list of neglected tropical diseases because they occur in areas where poverty is the most significant risk factor for their occurrence. These include Leishmaniasis, Trypanosomiasis, Chagas, Dengue, Lymphatic filariasis, and Onchocerciasis

The agents causing these diseases are protozoa, bacteria, viruses and filarial nematodes, and are transmitted by a range of arthropod vectors.

Let's first look at Protozoan agents and their associated disease, pathogens, vectors and transmission type. (**CHECK** – KT added). CLICK TWICE to get 'Protozoan' title and table to appear.

Vector-borne diseases of concern:
Viral

Disease	Pathogen	Vector	Transmission
Dengue*	*DEN-1,2,3,4 flaviviruses*	***Aedes aegypti* mosquito**	**Anthroponotic**
Yellow fever	*Yellow fever flavivirus*	***Aedes aegypti* mosquito**	**Anthroponotic**
Encephalitis (West Nile, Lyme, etc.)	*Flavi-, alpha- & bunyaviruses*	**Mosquitoes & ticks**	**Zoonotic**

* WHO neglected tropical disease

Source: Hill et al. (2005)

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There are many VBDs of concern, especially in developing countries, a number of which are on the WHO list of neglected tropical diseases (including Leishmaniasis, Trypanosomiasis, Chagas, Dengue, Lymphatic filariasis, and Onchocerciasis) because they occur in areas where poverty is the most significant risk factor for their occurrence.

The agents causing these diseases are protozoa, bacteria, viruses and filarial nematodes and are transmitted by a range of arthropod vectors.

Vector-borne diseases of concern:
Filarial nematodes

Disease	Pathogen	Vector	Transmission
Lymphatic filariasis*	*Brugia malayi, timori, Wuchereria bancrofti*	**Anopheles, Culex, Aedes mosquitoes**	**Anthroponotic**
Onchocerciasis*	*Onchocerca volvulus*	***Simulium* spp. blackflies**	**Anthroponotic**

* WHO neglected tropical disease

Source: Hill et al. (2005)

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Disease	Area	Cases-yr	C Con
Mosquito-borne diseases			
Malaria	Mainly Africa, SE Asia	about 220 million	
Dengue	100 countries esp Asia Pacific	about 50 million	
Tick-borne diseases			
Tick-borne encephalitis	Europe, Russian Fed Mongolia, China	about 10,000	
Lyme	Temperate areas of Europe, Asia, North America	about 20,000 in USA	
Other vector-borne diseases			
Hemorrhagic fever with renal syndrome (HFRS)	Global	0.15 – 0.2 million	
Plague	Endemic in many locations worldwide	about 40,000	

Direct effects of climate change on vector-borne disease

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Direct effects of climate change on vector-borne disease

Climate change has the potential to:

- Increase range or abundance of animal reservoirs &/or arthropod vectors
  - e.g. Malaria, Schistosomiasis, Lyme
- Enhance transmission
  - e.g. West Nile virus & other arboviruses
- Increase importation of vectors or pathogens
  - e.g. Dengue, Chikungunya, West Nile virus
- Increase animal disease risk & potential human risk
  - e.g. Trypanosomiasis

Source: Greer et al. (2008) 12

In terms of direct effects, climate has the potential to:

1. Increase the range or abundance of both animal reservoirs and arthropod vectors.

There is some emerging evidence of this occurring with Schistosomiasis in China and malaria in the Kenyan Highlands.

2. Climate change may also prolong the length of the transmission cycles of disease or the transmission season of diseases

West Nile virus (WNV), which has recently appeared in North America, has an amplification cycle involving mosquitoes and avian reservoir hosts. Human risk of infection is highest late in the summer when mosquito population densities are highest. Warmer spring and fall temperatures could increase the transmission season of the disease, thereby shifting the risk of human infection of the disease earlier in the summer.

3. Climate could also increase the likelihood of successful importation of disease vectors and animal host reservoirs.

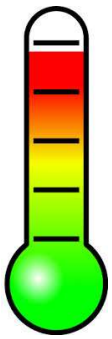
For example, the global spread of the Asian tiger mosquito, Aedes albopictus, which has been linked to the sale of used tires around the world, was linked to an outbreak of chikungunya virus, a dengue-like virus in Italy in 2007. Importation of a suitable animal reservoir is believed to be one of the possible methods of introduction of WNV to North America in the late 1990s.

4. As mentioned previously, climate change effects resulting in increased animal incidence of disease are likely to increase the risk of human disease as well.

Temperature effects on vectors & pathogens

Vector

- Survival decrease/increase depending on the species
- Changes in the susceptibility of vectors to some pathogens
- Changes in rate of vector population growth
- Changes in feeding rate & host contact



Source: Gubler et al. (2001)

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Temperature can affect both the distribution of the vector and the effectiveness of pathogen transmission through the vector.

Gubler et al. (2001) list a range of possible mechanisms whereby changes in temperature impact on the risk of transmission of VBD:

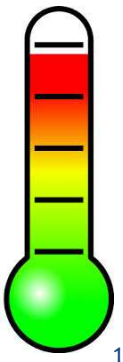
Temperature may act to:

- Increase or decrease vector survival
- Change the rate of vector population growth
- Change the feeding behavior of vectors
- Change the susceptibility of vector to pathogens
- Change the incubation period of pathogens in vectors
- Change the seasonality of vector activity
- Change the seasonality of pathogen transmission
- Vector is infective.

Temperature effects on vectors & pathogens

Pathogen

- Decreased extrinsic incubation period of pathogen in vector at higher temperatures
- Changes in the transmission season
- Changes in geographical distribution
- Decreased viral replication



Source: Gubler et al. (2001)

14

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- Change the susceptibility of vector to pathogens
- Change the incubation period of pathogens in vectors
- Change the seasonality of vector activity
- Change the seasonality of pathogen transmission
- Vector is infective.

Precipitation effects on vectors

Vector

- Survival: increased rain may increase larval habitat
- Excess rain can eliminate habitat by flooding
- Low rainfall can create habitat as rivers dry into pools (dry season malaria)
- Decreased rain can increase container-breeding mosquitoes by forcing increased water storage
- Heavy rainfall events can synchronize vector host-seeking & virus transmission
- Increased humidity increases vector survival & vice-versa

Source: Gubler et al. (2001)

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Precipitation can also have a number of effects on vectors.

Gubler et al. 2001 highlight that:

Precipitation effects could include:

• Increased surface water thereby providing increased breeding sites for vectors
• Decreased rainfall could also increase breeding sites by slowing river flow
• Increased rain could increase vegetation and allow expansion in populations of vertebrate host
• Flooding could eliminate habitat for both vectors and vertebrate hosts
• Flooding could also force vertebrate hosts into closer contact with humans.

Precipitation effects on pathogens

Pathogen

- Few direct effects but some data on humidity effects on malarial parasite development

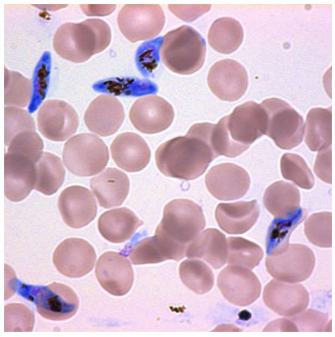

Photo: Science Daily

Source: Gubler et al. (2001)

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Precipitation – and particularly humidity with precipitation - can also effects the development of malarial parasites.

(If asked: In this image shown in blue are Plasmodium falciparum malaria parasites in the sexual, gametocyte stage of development. In red are uninfected red blood cells.)

Vector activity

- Increased relative humidity increases activity, heavy rainfall decreases activity
- Increased activity increases transmission rates

Photo: National Geographic

Photo: Ranger DJ

Source: Ogden et al. (2005), Vail & Smith (1998)

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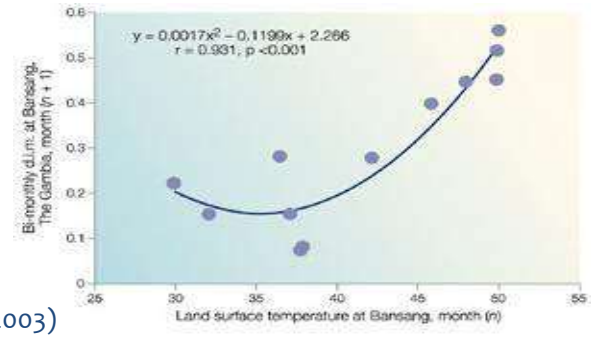
Humidity and precipitation can also have a significant role in vector activity. A greater relative humidity can increase vector activity, but heavy rainfall can actually decrease activity.

Increased activity increases transmission rates.

Vector survival

- Direct effects of temperature on mortality rates*
- Temperature effects on development: at low temperatures, lifecycle lengthens & mortality outstrips fecundity*

Tsetse mortality



* Non-linear (quadratic) relationships with temperature

Source: Rogers & Randolph (2003)

Relationship between temperature and vector mortality is quadratic: mortality rates increase at high and low temperatures.

Temperature effects on development may affect mortality rates: particularly high rates of development of mosquitoes can result in small adults with poorer survival. This is one example where the terms in epidemiological models of VBDs interact with one another. Another important interaction is the dependence of transmission coefficients for tick-borne pathogens on the numbers of vectors feeding on the host. The understanding of such interactions is, however, largely rudimentary.

When relative humidity is low, ticks have to make more frequent, energy-expensive trips to the litter layer to rehydrate. High "monsoon" rainfall knocks ticks off the herbage and prevents them from finding a host.

Lower humidity ↑ the energy requirement for host seeking by ticks shortening their lives.*

Lower rainfall ↓ breeding areas for mosquitoes, compounded by density-dependent intraspecific competition amongst larvae.

More complex community-associated changes (habitat structure, predator abundance).

Vector & host seasonality

- Vector-borne zoonoses mostly maintained by wildlife
- Vectors & their hosts are subject to seasonal variations that are climate related (e.g. temperature) & climate independent (e.g. day-length)
- Seasonal variations affect abundance & demographic processes of both vectors & hosts

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Many VBDs are zoonotic and have life cycles that are fully maintained in wildlife.

In these diseases, seasons often play a very important role in the relationships between vectors and hosts.

Vector & host seasonality

- Vector seasonality due to temperature affects development & activity → transmission
- Host demographic processes (reproduction, birth & mortality rates), affected directly by weather & indirectly by resource availability → VBD epidemiology

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Both vectors and hosts have seasonal variations in their life cycles driven by seasonal changes in climate and climate independent effects such as day length.

• Vectors can be affected by the way in which temperature can change from season to season, with resultant impacts on their development, activity, and disease transmission role.

• The lifecycle and activity level of the host can be affected as well, affecting how fast infected or immune animals die and how fast uninfected animals are borne, with resultant impacts on the epidemiology of vector-borne zoonoses.

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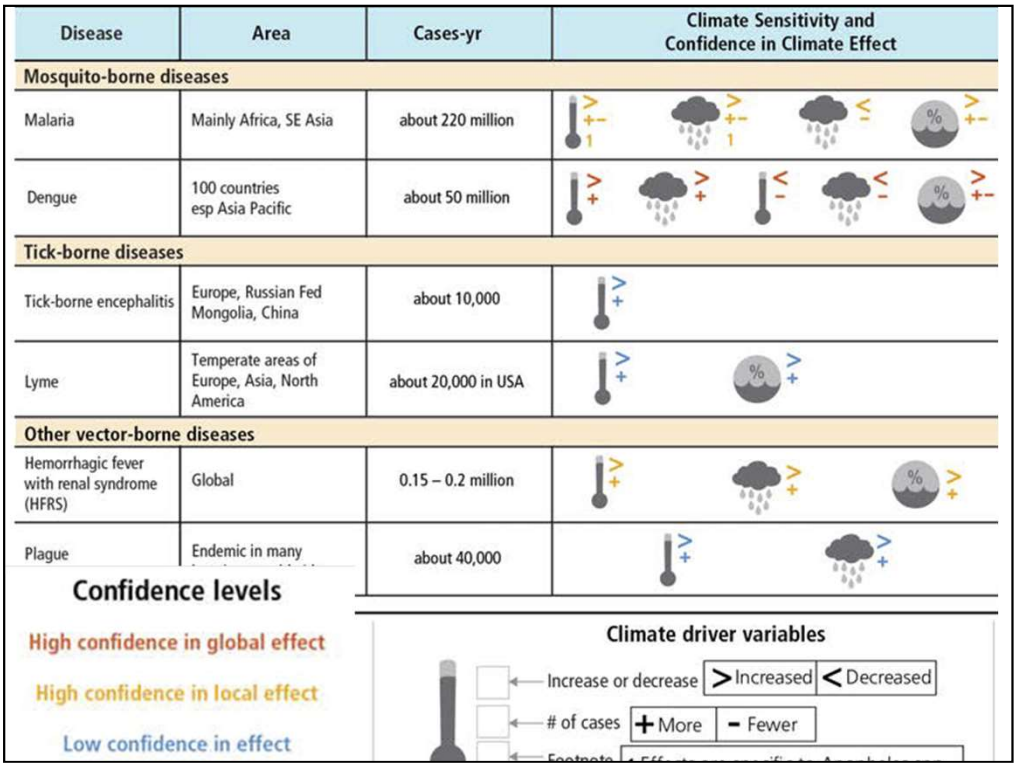

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Mosquito-borne diseases			
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The latest IPCC report shows the association between different climatic drivers and the global prevalence and geographic distribution of selected vector-borne diseases observed over the period 2008-2012.

CLICK *to animate the image to full screen.* ***CLICK again*** *to show the key for the confidence levels shown in the table.*

Among the vector borne diseases shown here, only dengue fever was associated with climate variables at both the global and local levels (high confidence), while malaria and hemorrhagic fever with renal syndrome showed a positive association at the local level (high confidence)

Evidence of climate change effects

Some specific disease examples:

- Malaria - East African highlands
- Schistosomiasis - China

Photo: CDC

Photo: USDA

Photo: Davies Laboratory

Photo: CDC

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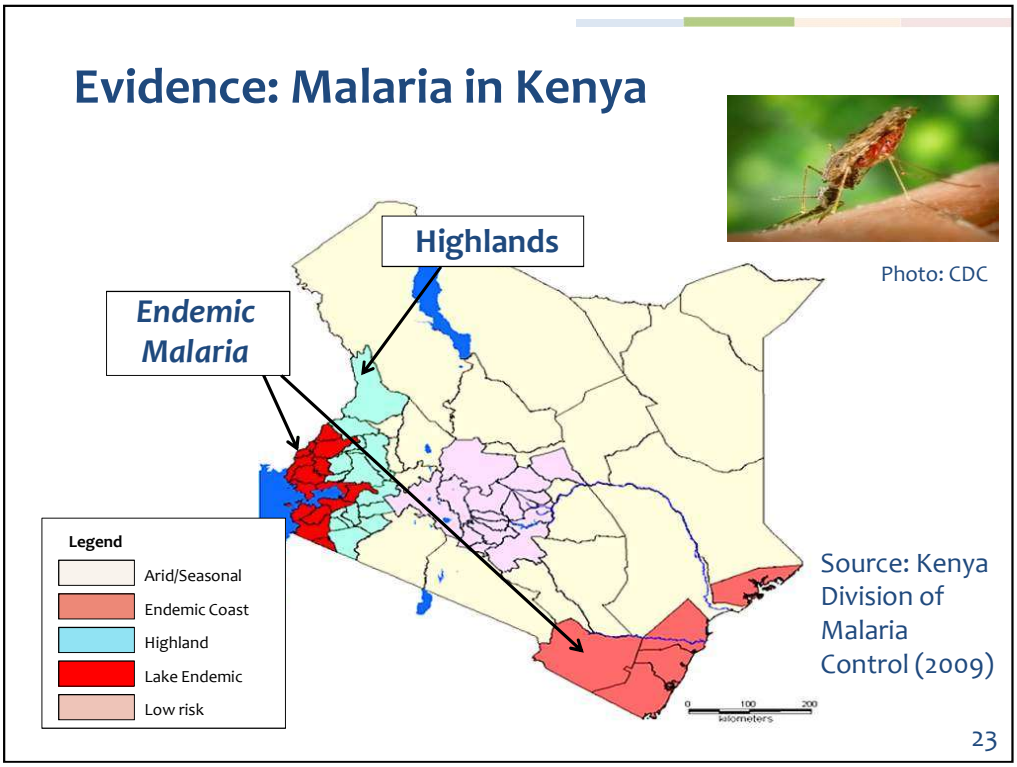
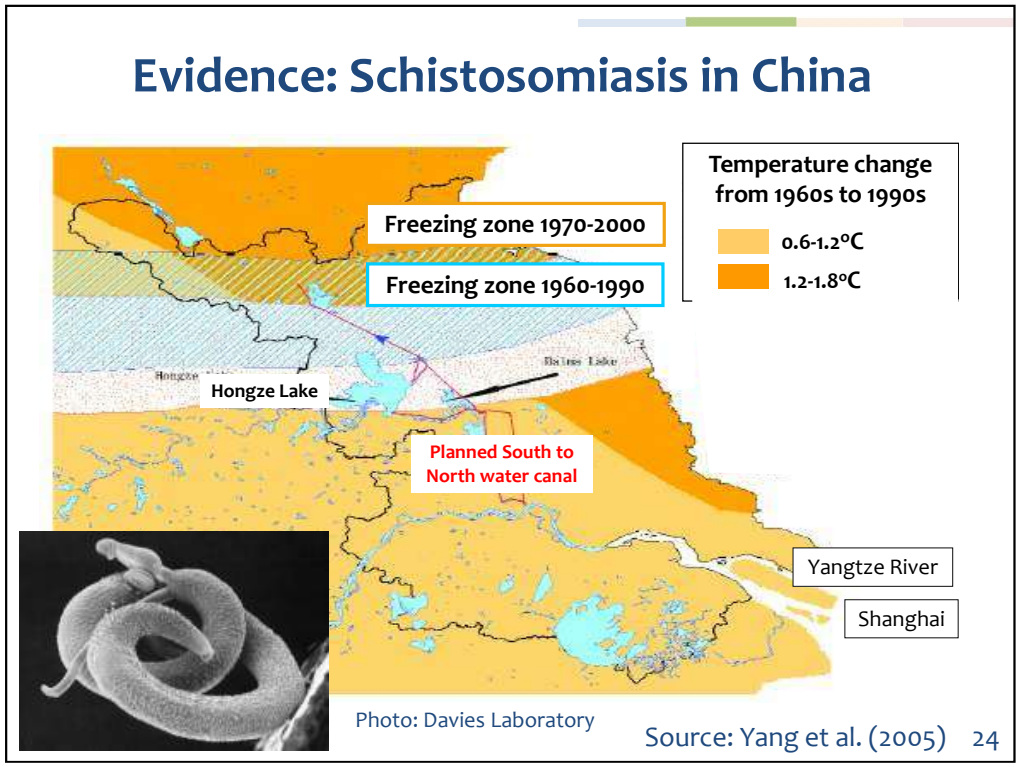
In the next section, we will be looking at evidence of climate change effects. We will review some specific examples that provide some potential evidence of the effects of climate change on VBD. Our examples will include malaria, schistosomiasis, and bluetongue disease.



A study by Pascual et al. (2006) reviewed temperature data for the past 50 years in East Africa to examine the role of climate in exacerbating incidence of endemic malaria in the Eastern highlands of Kenya where increases in malaria have been observed since the 1970s.

Their analysis found evidence for significant warming at all sites and an applied dynamic model suggested that biological responses, such as those by the vector and pathogen, would also be magnified by at least 1 order of magnitude under climate warming.

The map you see in the slide shows the different areas of Kenya and the different incidence rates. The bright red portion of the map shows an area with endemic malaria. The pink area on the coast also shows an area with endemic malaria. The aqua section of the map that abuts the red endemic area is the "Highlands" area, where incidence has been increasing.



The next example looks at Schistosomiasis in China.

There has been a northwards extension of potential transmission (limited by "freezing zone"), in Jiangsu Province, due to a rise in the average temperature in January since 1960.

The study by Yang et al. (2005) noted an increase in the reported incidence of Schistosomiasis over the past decade which may reflect the recent warming.

The northwards expansion of the "freeze line" (which limits survival of water snails) puts 21 million extra people at risk.

Summary of climate change effects

Climate change has the potential to:

- Increase range or abundance of animal reservoirs &/or arthropod vectors
  - Lyme, Malaria, Schistosomiasis
- Prolong transmission cycle
  - Malaria, West Nile virus, & other arboviruses
- Increase importation of vectors or animal reservoirs
  - Dengue, Chikungunya, West Nile virus
- Increase animal disease risk & potential human risk
  - African trypanosomiasis

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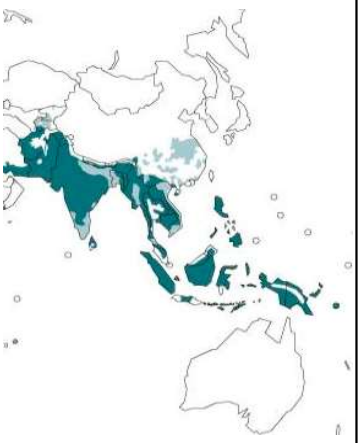
As a quick recap:

The major ways in which climate change is likely to impact VBD include

1. Increasing the range or abundance of animal reservoir and arthropod vectors
2. Prolonging the transmission cycle of disease
3. Increasing the likelihood of successful importation of disease vectors or animal reservoirs
4. Increasing the animal disease risk and potential human risks of disease.

Case studies of climate change effects on VBD



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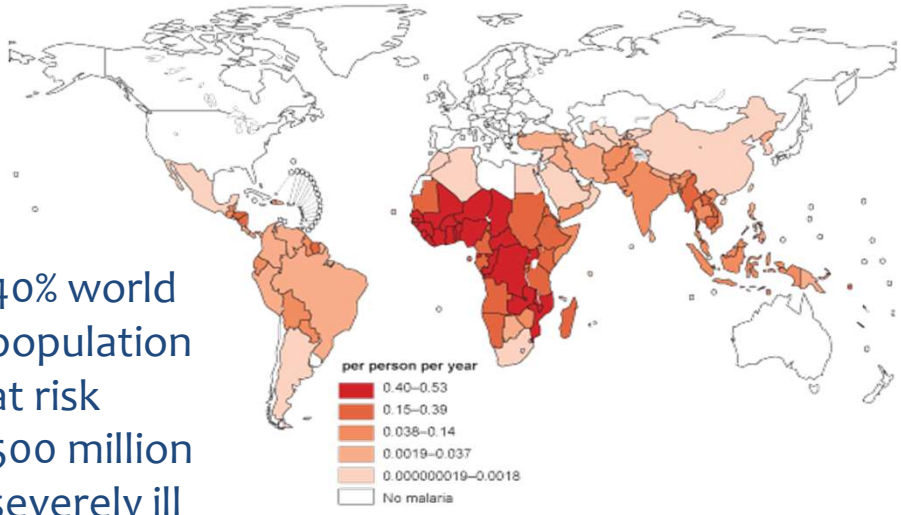
Case Study 1: Malaria

Estimated incidence of clinical malaria episodes



- 40% world population at risk
- 500 million severely ill

Source: WHO 27

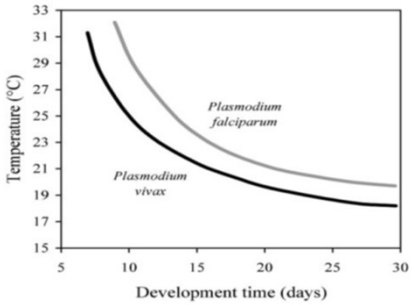
Now we will move onto discussing some case studies of VBDs and how their transmission can be affected by climate.

The first case study that we will discuss is malaria. **Year for WHO image?**

- Approximately 40% of the world's population lives in areas at risk for malaria.
- Every year about 500 million people become severely ill from malaria.
- Between 700,000 and 2.7 million – mostly children in sub-Saharan Africa – die each year of malaria.

Malaria & climate

- Climate sensitive disease[1]
  - No transmission where mosquitoes cannot survive
  - *Anopheles*: optimal adult development 28-32°C
  - *P falciparum* transmission: 16-33°C
- Highland malaria[2]
  - Areas on the edges of endemic regions
- Global warming → El Niño[3]
  - Outbreaks



Source: McDonald et al. (1957)

[1] Khasnis & Nettleman (2005); [2] Patz & Olson (2006); [3] Haines & Patz (2004)

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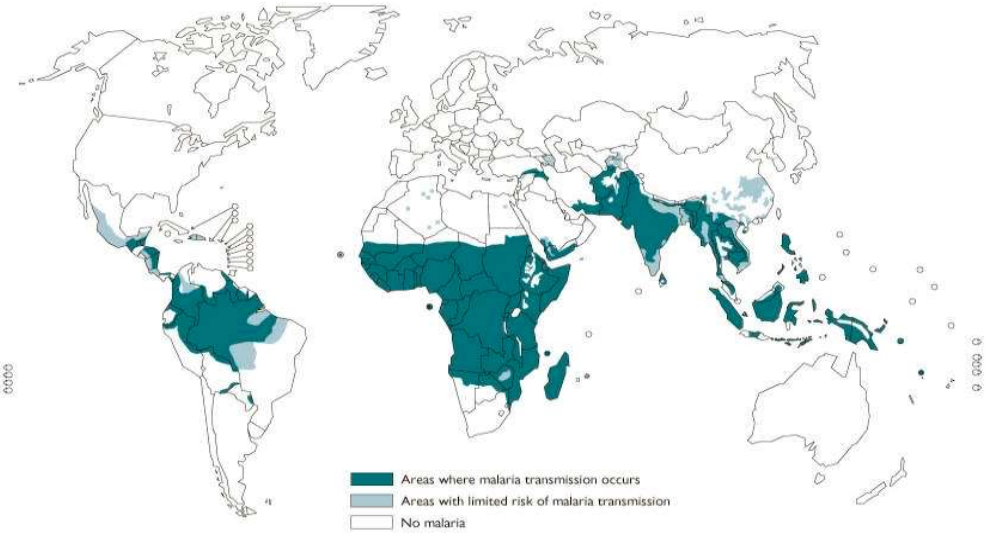
The effect of climate change on malaria remains in debate.

But malaria is an extremely climate sensitive disease. **Clearly transmission does not occur in climates where mosquitoes cannot survive.** Optimal larval development occurs at 28° C and optimal adult development between 28 and 32° C, as you can see in this temperature and development graph on the right. Transmission cannot occur below 16° C or above 33° C as sporogony (the production of sporozoites which comprises dissemination and development of the parasite in the vector) cannot take place.

The effect of global warming on malaria may be felt most in areas that are currently on the edges of the range of infected mosquitoes (Patz and Olson, 2006). These include many of the densely populated highland regions in Africa that are surrounded by lowland areas where malaria is endemic. Small changes may therefore lead to the exposure of many people to malaria.

Many global warming scenarios include an increase in the frequency and intensity of the El Niño phenomenon (Patz et al., 2002) such as storms, heavy rain, droughts, and warm temperature. El Niño seasons have been associated, although not always, with outbreaks of malaria in many areas (ref Atul). Therefore it seems reasonable to speculate that the intensification of El Niño effects due to global warming will facilitate local epidemics of malaria.

Malaria transmission map



Source: WHO (2008)

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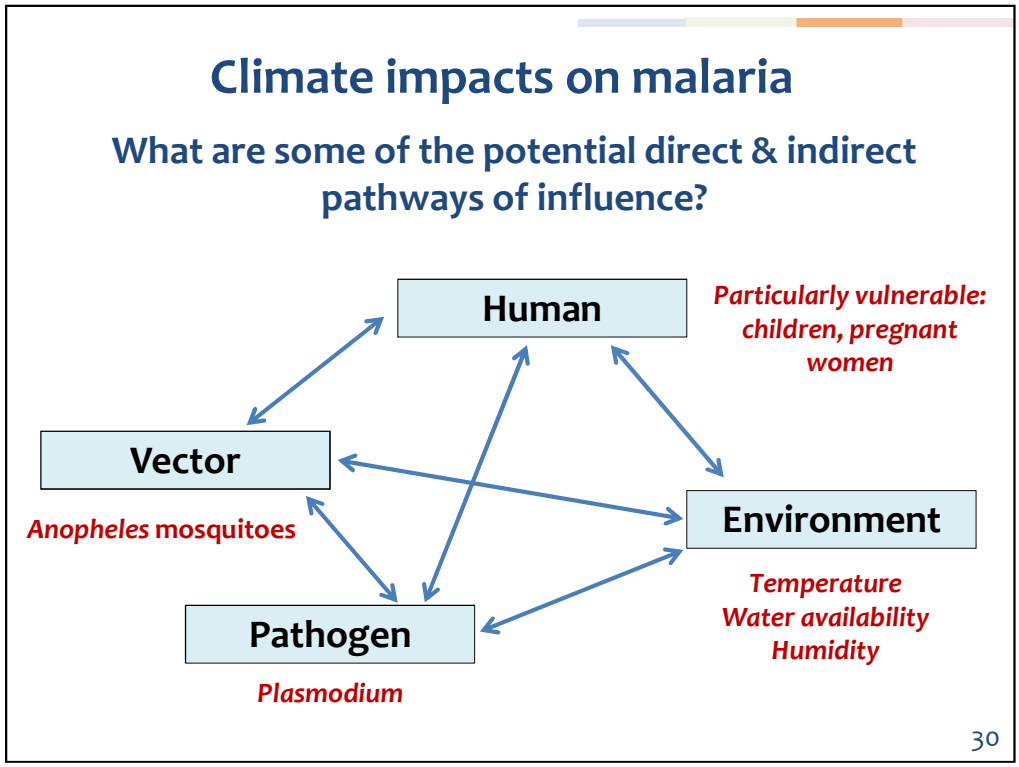
This is a map of the current distribution of malaria transmission, with the dark areas those where malaria transmission occurs.

Transmission zones are highly dependent on climate. Localized transmission is affected by regional factors (such as type of vegetation, health services, vector control), but the global ranges are predominantly affected by climate. The key areas of importance for climate change will be changes (loss or appearance) of incidence at the margins of these ranges, where climate suitability for the vector and/or pathogen are currently marginal, and where small shifts in climate may push the transmission potential of the disease above or below the required threshold.

•There will likely be areas of decline and areas of emergence
• Impacts are likely to depend on localized factors and a combination of climate and socioeconomic conditions
• Risk will increase the most on the fringes of malarial transmission, but control is generally good in these areas
• Impacts will likely remain highest in currently endemic areas, where control is poor and vulnerability is high.



This slide will examine the role of climate impacts on the vector, the pathogen, and humans.

Vector:
The malaria vector is the Anopheles mosquito. Several key transmission variables can be affected by climate. Most important are the climatic requirements for survival. Different species require different temperature ranges.

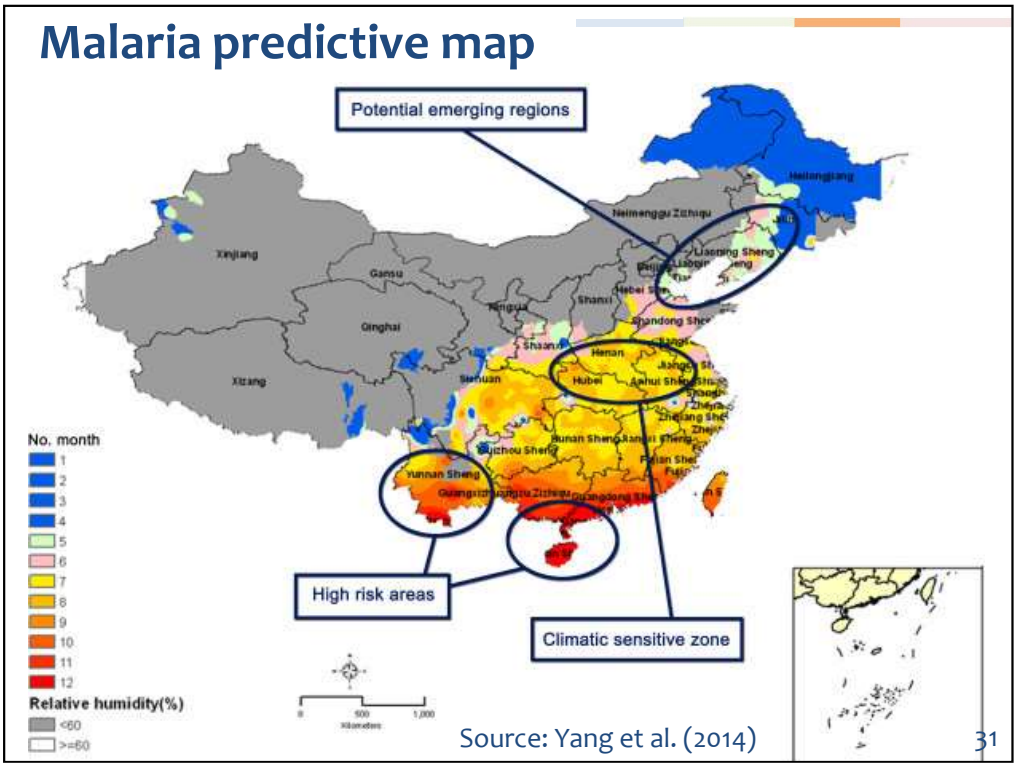
Key vector factors:
• Climatic requirements for survival
• Temperature ranges for different species
• Standing water and humidity requirements
• Insecticide resistance (e.g., DDT).

Pathogen:
The malaria pathogen is the Plasmodium parasite. Common species include *P. falciparum, P. vivax*, and *P. malariae*. The pathogen requires a certain temperature for reproduction.

Human population:
The human population can be affected by climate and the environment as well. Climatic change can affect the ability of the human population to access medical treatment. Climate can also affect patterns of human movement, contributing to the spread of transmission to new areas.

Key human population factors:
• Poverty and other social determinants of health
• Acquired immunity

- Access to medical treatment
- Resilience capacity: knowledge of how environmental factors affect malaria (i.e water management).

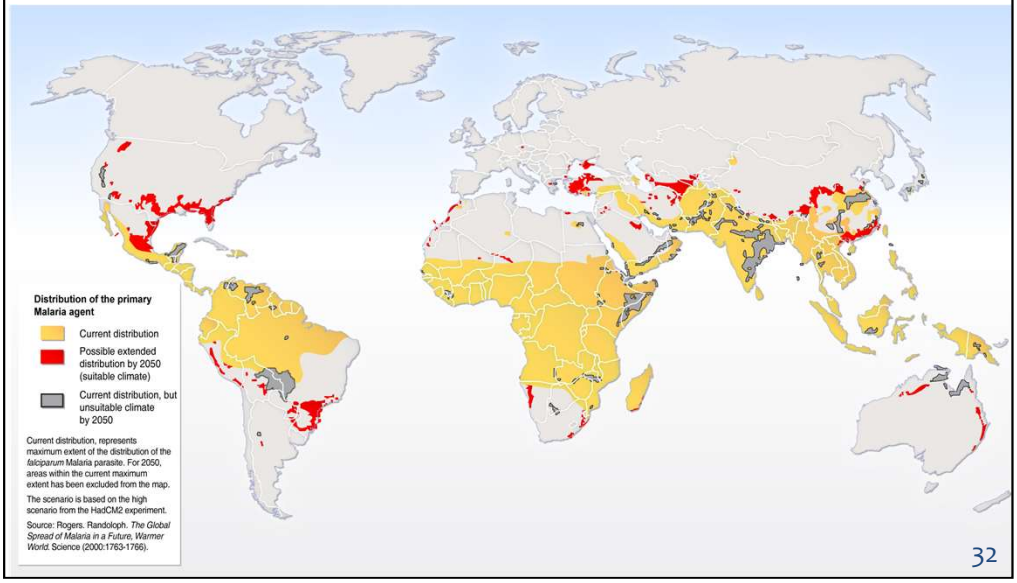


The figure shows a predictive map for malaria according to multiple environmental factors. These maps predict that P. vivax malaria mainly occurs in the south-eastern part of P.R. China with the risk of malaria increasing steadily from north to south. Comparison between different decades shows that there is a high probability that variables suitable for malaria transmission will shift northwards, mainly driven by relative humidity (RH)

In the southern and south-eastern region of China where is the high risk areas for malaria transmission, the passive and active surveillance approaches identified. In the central region where is the climate sensitive zone to the malaria transmission, an appropriate surveillance-response approach is necessary to develop. In the north-eastern region where is potential malaria emerging regions due to climate change, the continuous surveillance and monitoring is warranted

Climate change & malaria scenario

Source: UNEP/GRID-Arendal (2005)



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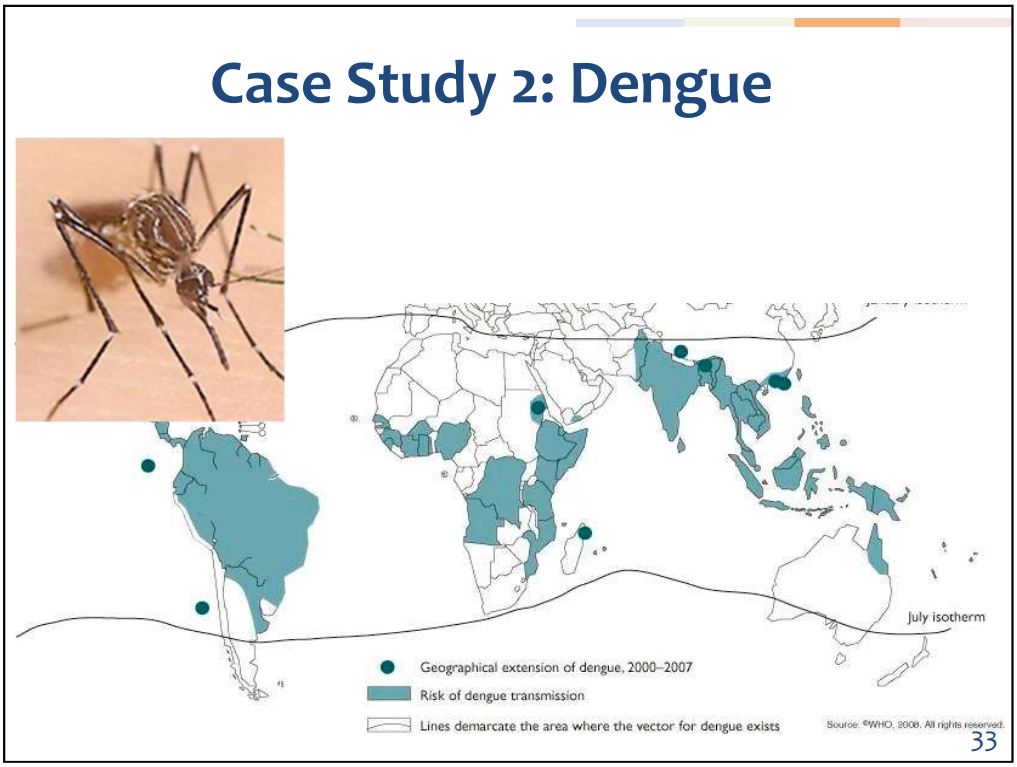
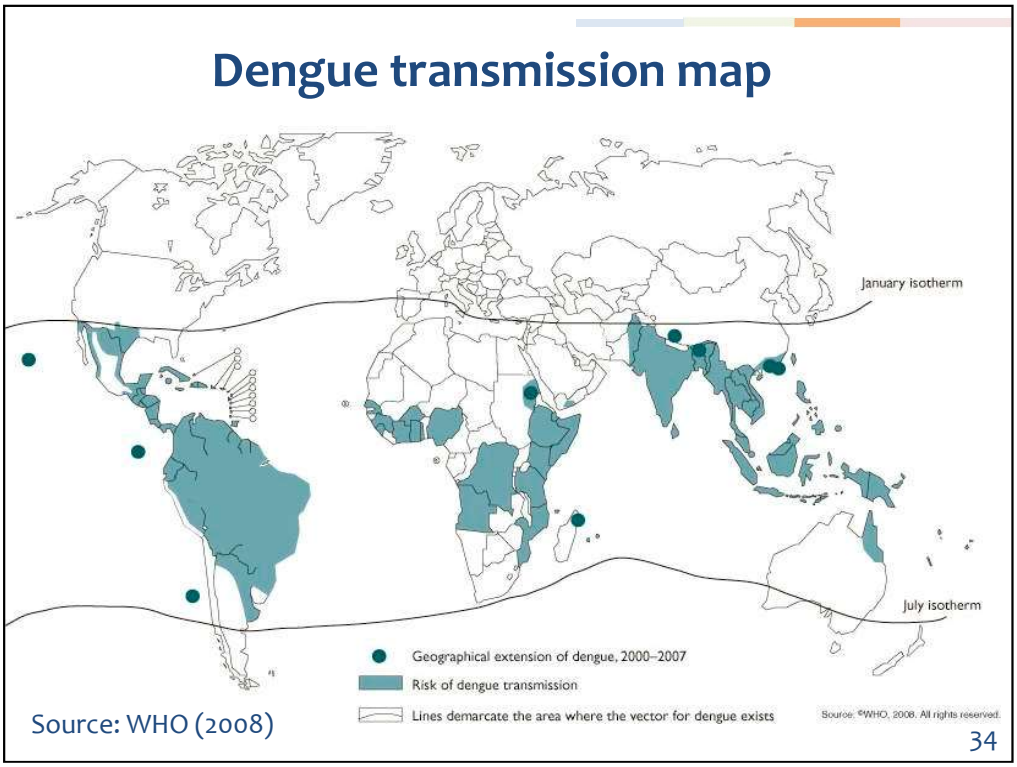
With climate conditions changing in the future, due to increased concentrations of carbon dioxide in the atmosphere, conditions for pests also change. The primary Malaria agent, the falciparum malaria parasite, will be able to spread into new areas, as displayed in this map, by 2050 using the Hadley CM2 high scenario



The next case study that we will discuss is dengue.

Dengue is the most rapidly spreading mosquito-borne viral disease, showing a 30-fold increase in global incidence
over the past 50 years (WHO, 2013). Each year there occur about 390 million dengue infections worldwide, of which roughly 96 million manifest with symptoms (Bhatt et al., 2013). Three quarters of the people exposed to dengue are in the Asia-Pacific region



This is the current area at risk of dengue transmission in more detail.

The lines represent January and July isotherms and demarcate the area where the vector for dengue exists.

Climate change is likely to shift these isotherms farther north above the equator and farther south below the equator, thereby potentially increasing the size of the area at risk of dengue transmission.

Climate variability & dengue incidence

***Aedes* mosquito breeding (Argentina)[1]:**

- Highest abundance mean temperature 20°C, ↑ accumulated rainfall (150 mm)
- Decline in egg laying at monthly mean temperatures <16,5°C
- No eggs at temperatures <14,8°C

Other studies:

- Virus replication increases ↑ temperature[2]
- Transmission of pathogen ≠ >12°C[3]
- Biological models: small ↑ temperature in temperate regions → increases potential epidemics[4]

Sources: [1]Vezzani et al. (2004); [2]Watts et al. (1987); [3]Patz et al. (2006); [4]Patz et al. (1998)

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Dengue is an important mosquito-born disease, with about 2.5 billion people at risk worldwide.

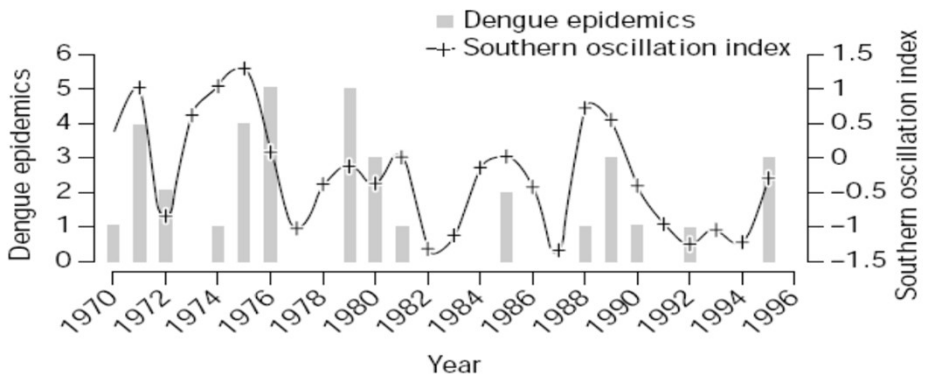
The *Aedes* spp. mosquito vectors are well adapted to the urban environment and thrive well in a warm, humid environment. Viral replication in the vector increases with temperature, with expected temperature-related effects on transmission. Minimal transmission temperature for the dengue virus is 12° C.

Dengue hemorrhagic fever (DHF) outbreak in southern Sumatra was accompanied by more extreme weather due to El Niño effects (Corwin et al., 2001).

Linked to future climate change projections, a small rise in temperature in temperate regions will increase the potential for future epidemics, given a susceptible population and introduction of the virus.

Example of weather effects: El Niño

- Global warming intensifies El Niño
- Several studies found relationships between dengue epidemics & ENSO (El Niño Southern Oscillation)



Sources: Hales et al. (1999), Tipayamongkholgul et al. (2009)

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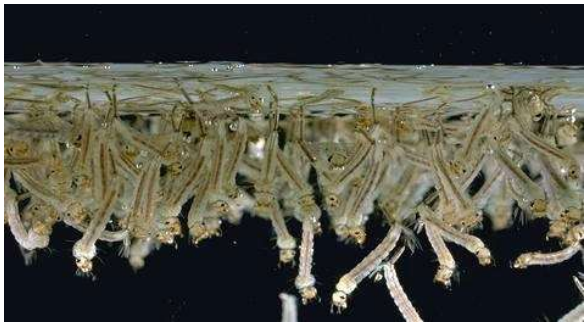
Several studies have found relationships between dengue epidemics and ENSO (El Niño Southern Oscillation). ENSO is a global scale pattern of climate variation that accounts for up to 40% of temperature and rainfall variation in the Pacific. Both drought conditions and the rainfall accumulation following a drought contribute to augmentation of the vector population.

Example of weather effects: El Niño

- Drought conditions: increase water storage around houses → elevated *Aedes aegypti* populations
- Enhanced breeding opportunities when rainfall accumulates following drought



Sources: Kuno et al. (1995)

Photo: University of California

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Several studies have found relationships between dengue epidemics and ENSO (El Niño Southern Oscillation). ENSO is a global scale pattern of climate variation that accounts for up to 40% of temperature and rainfall variation in the Pacific. Both drought conditions and the rainfall accumulation following a drought contribute to augmentation of the vector population.

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Potential of adaptation to minimize VBD health risks & impacts

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Opportunities for adaptation

- Strengthening surveillance
- Adopting a precautionary approach
- Mainstreaming response to disease threats
- Enhancing health system capacity
- Anticipating new & emergent pathogens & their potential to change current VBD burden

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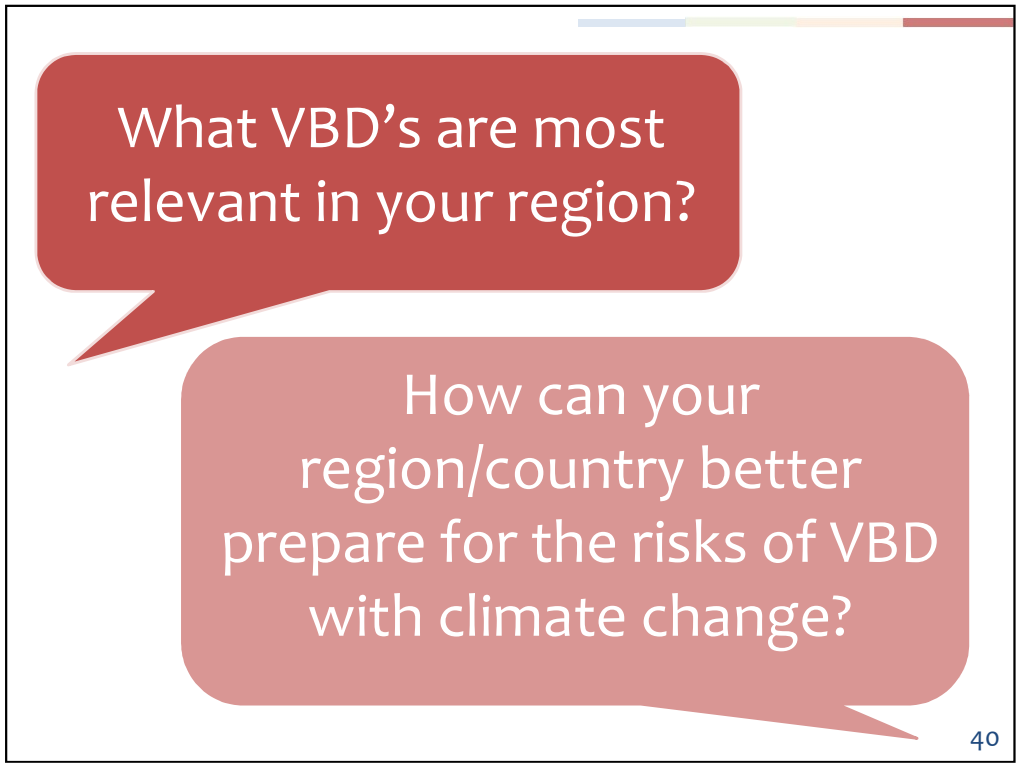
Adaptation measures which can be implemented to reduce current and future disease threats include:

• Strengthening surveillance and public health
• Adopting precautionary approaches in health planning and disease monitoring
• Mainstreaming response to disease threats
• Enhancing health system capacity to handle current and anticipated future disease risks
• Anticipating the potential for new and emergent VBD pathogens and their potential to change the current VBD burden.

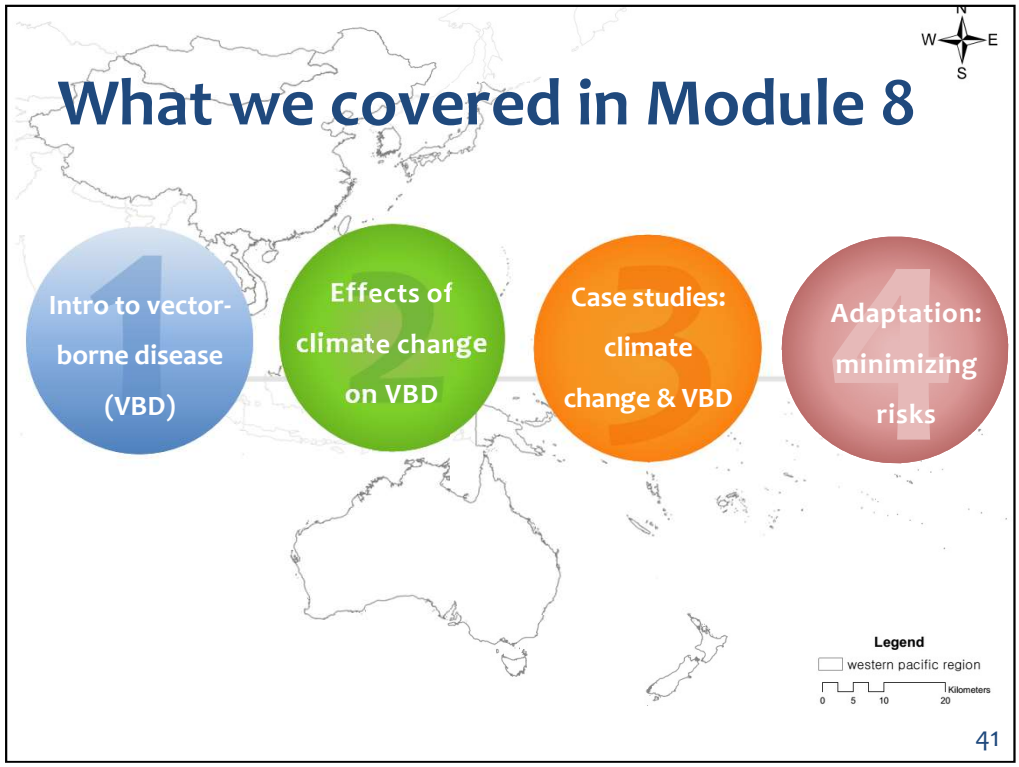


"To finish off, in a minute I'd like you to stand up, move to somewhere else in the room and find another person to chat with. Introduce yourself, and then discuss what VBD's are most relevant in your region.

Secondly, what ideas do you each have for how you can prepare for the risks of VBD under climate change?

You'll have 4 minutes."

Give time count down – **3 minutes**: "Ok, you have 1 more minute to wrap up your conversation. When you've finished, please return to your seat." **4 minutes**: "Thanks everybody. Thank your partner and return to your seats."



We just discussed the potential for adaptation to minimize health risks and impacts from vector-borne diseases.

Before that we looked at:

1. An introduction to vector-borne diseases
2. The effects of climate change on VBD; and
3. Some case studies of climate change effects on VBD

Learning from Module 8

- Climate change could affect vector-borne disease (VBD) in humans
- Climate change affects vector-borne diseases through several mechanisms
- Impacts will vary from region to region
- Current evidence suggests impacts on some diseases may already be occurring
- Impacts may include unanticipated emergence of new pathogens

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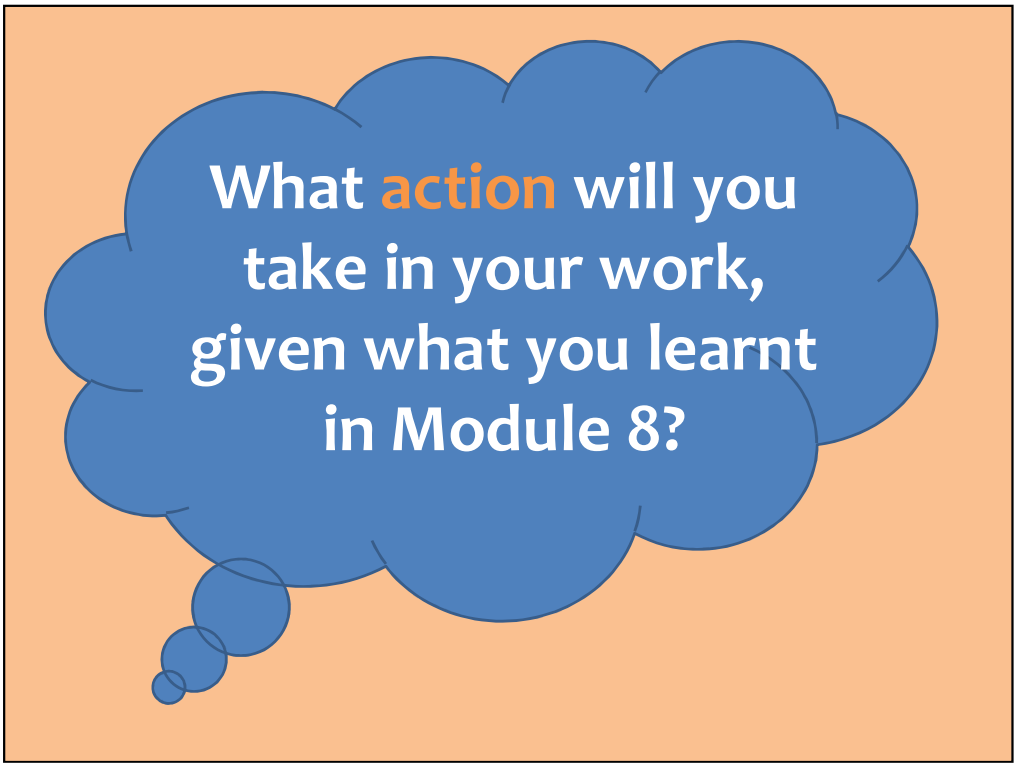
Across those four areas, the key learnings to take away from this module are:

• It is likely that climate change will affect the distribution and incidence of VBD globally
• impacts will vary from region to region
• Current evidence uncovered to date suggests that impacts on some diseases may already be occurring

In addition:
• Some of the potential impacts of climate change may include the unanticipated emergence of new pathogens.

Recommended further reading: 2007 IPCC report: The Physical Science Basis, FAQ 3.1 page 103 and FAQ 3.2 page 105



To finish off Module 8, I'll ask you to spend the next few minutes looking over your notes and reflecting on the key learnings from Module 8 for you.

Please take some notes on any action steps you'd like to take once you're back at work, based on what you've learnt around vector-borne diseases and climate change.

Encourage quiet reflection (verbally if needed). At the end of 2 minutes: "Thanks. I look forward to hearing some of the actions that were captured over the coming days."

Coming up next…

Module 9:

Water & food-borne diseases

Coming up next, we'll look specifically at diseases that are water and food-borne – another important area of climate change preparedness for health practitioners.