List of slides and explanatory notes

Topic C: Vector habitats

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C.11 Malaria vector species and their ecological requirements; a transsect of the Malaysian peninsula

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C.14 Malaria vector habitats: *Anopheles maculatus* breeding places in rice growing areas in Nepal
C.15 Malaria vector habitats: irrigated rice fields, Office du Niger, in Mali, where a succession of species breeds

C.16 Malaria vector habitats: *Anopheles gambiae* breeding in exposed pools

C.17 Malaria vector habitats: *Anopheles gambiae* breeding rooftop tanks, Mauritius

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C.19 Natural habitat suited to the breeding of simuliid black flies

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C.22 Landscape typifying sandfly habitat in the arid, northern Kenya (termite mound)

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Credit individual slides:

World Health Organization: all

Slide C.1

Slide C.2

Slide C.3

These three matrices provide a complete picture of the associations between eco-zones, vectors and diseases. This is a general picture. The local situation will be defined by micro-habitats and micro-climates, and the intensity of associations will vary over time in relation to the weather and, for instance, the cropping cycle. An assessment of the local situation always requires an epidemiologist and a vector specialists knowledgeable of local disease patterns and the ecology and biology of local vectors.

The matrices are designed to facilitate a rapid health impact assessment of water resources development projects and are published in PEEM guidelines no. 2.

Slide C.4

Slide C.5

Many large dams were constructed and reservoirs created in the 1960s and 1970s in Africa. They invariably created health problems, amongst which schistosomiasis scored high, particularly in communities of fishermen on the shores of the new man-made lakes. Perhaps more insidious, however, are the thousands of small dams that have been built all over the continent in the face of droughts, the need for increased food production
through small scale irrigation and the water needs of expanding livestock populations. Their cumulative effect on health is likely to be substantial, but has not been documented.

Small reservoirs provide the habitat requirements for snails as presented in these slides. Temperature, availability of organic material and aquatic vegetation that serves as a refuge are crucial components of the snail habitat.

**Slide C.6**

Snails need a substrate (soil or vegetation) from where to scrape of organic matter for their nutrition. For more detailed information on the feeding behaviour of snails, reference is made to specialist literature (see bibliography).

**Slide C.7**

**Slide C.8**

**Slide C.9**

**Slide C.10**

In all these locations snail species have been found that can serve as intermediate hosts for schistosomiasis. However, this only indicates the hazard or potential risk. Other elements need to be present to establish transmission: contamination of the aquatic environment with parasite eggs in either urine or feces of human origin; and, regular water contact by people with the contaminated water. Shallow wells are unlikely to be contaminated because local customs usually aim at protecting them. Irrigation basins and other concrete hydraulic structures, on the other hand, frequently become a site where children bathe and swim (and, possibly, urinate or defecate) and where transmission can be intense. They may, at the same time serve as laundry place, where women have intense water contact. Drainage canals in irrigation schemes tend to have more aquatic weed growth then irrigation canals. In the system’s run-off water natural minerals as well as excess fertilizer will provide more than sufficient nutrition for such vegetation. Burrow pits, places where soil is removed for construction purposes, become large aquaria where snail populations can thrive in stagnant water. Along new roads or near new settlements, such water collections can become important transmission sites as well as sources of nuisance or vector mosquitoes. On a larger scale, night storage dams in irrigation schemes can become important transmission sites for schistosomiasis.

**Slide C.11**

The situation in Malaysia proved ideal for the development of early environmental management approaches and the following section taken from the publication of Takken *et al.* (1991, see bibliography) gives a complete summary of this:

**Species sanitation**
When in 1897 Ross published his findings on the development of *Plasmodium* inside the mosquito, and it was subsequently demonstrated that mosquitoes of the genus *Anopheles* were responsible for the transmission of malaria, it was soon realized that changing the aquatic habitat of the vectors would automatically lead to interruption of malaria transmission. The most well known example of this method is the drainage of the marshes near Rome, Italy. Malaria control through habitat modification was at that time also attempted in Indonesia by filling small water bodies with soil, especially close to areas of human habitation. In Malaysia, Watson (1911) experimented with the selective elimination of one species, *Anopheles umbrosus*, which had been incriminated as the principal malaria vector in a lowland area. Watson had previously found that not all the anopheline species in the area were responsible for malaria transmission and had also found that these mosquitoes were often restricted to a specialized breeding habitat (the same would be discovered by Jennings in Central America in 1912). Through the selective clearing of wooded habitat, the shade loving *A. umbrosus* was being exposed to the sun and subsequently disappeared. The previously widely present malaria went with it. This proved to be an economical method of malaria control: by identifying the most important vector and the subsequent study of its biology and ecology, malaria control had been achieved without having to eliminate all anopheline species present.

Watson discussed his findings with Swellengrebel on Sumatra (Indonesia) in 1913. The latter became deeply interested in this method and called it *species sanitation*. This is the term with which we still identify the method today. It is defined as a naturalistic approach to vector control, directed against the main vectors, through modification of the habitat in such a way that the vectors avoid these areas. The method requires a study of the characteristic breeding habits of the main vectors and of the type of water in which they lay their eggs. Control is mostly directed against larval stages, but sometimes adults can be included as well. Species sanitation has the advantage over general sanitation that often only one of a complex of several *Anopheles* species needs to be attacked.

(From: Takken, W., et al., 1991. Environmental measures for malaria control in Indonesia, chapter 2, without quoting further references).

Regrettably, this situation with clearly identifiable micro-habitats for different vector species is not common. The vector species in Africa, for instance, are much more versatile and adaptable in terms of habitat requirements, and species sanitation has therefore only had a restricted application under very specific conditions.

*Slide C.12*

Some malaria vectors (*Anopheles sundaicus* with a distribution from the East coast of India to Viet Nam and the Indonesian islands; *A. albimanus* on the Pacific coast of Central America) require a brackish water environment for their larval stages. Managing the water flows in mangrove areas and estuaries to ensure that salt levels are maintained outside of the range needed by these species help to keep vector populations down. A lot of work was done in the Dutch East Indies, present-day Indonesia, in the 1930s, in connection with ponds for shrimp culture. Work in El Salvador (Ticuizapa Estero) by Frederickson in 1986-1987 (as part of the USAID Vector Biology and Control Project) demonstrated that environmental management (removal of a sand
bar, allowing the drainage of water from the estuary at low tide, and blocking the influx of sea water at high tide) can provide a lasting solution to malaria transmission.

Reports of the Vector Biology and Control Project, including the reports on the environmental management activities, belong to the grey literature. Information can, however, be obtained from the PEEM Secretariat, WHO, Geneva, Switzerland, where a full set of these reports is available.

In South-East Asia and the archipelagos of Indonesia and part of the Philippines the most important vectors belong to the *Anopheles dirus* species complex or to the *Anopheles balabacensis* species. Tropical forests provide the essential habitat for these vectors, where they breed in small pools and other water collections in the vegetation, and where a high relative humidity creates favourable conditions for extended longevity. As a result, they are efficient vectors and maintain transmission amongst those workers who depend on the forest for their livelihood. Their role in the transmission of malaria in the forested border areas of Thailand with Myanmar and Cambodia is notorious.

Wherever deforestation occurs, transmission by these anophelines immediately declines. Re-afforestation and the introduction of plantations of rubber or fruit trees recreates the appropriate environment. Moreover, the exploitation of plantations requires more humans to be exposed to the transmission risks or contributing to the transmission cycle. Often, the work in plantations requires people to be exposed to mosquito bites at the peak biting times.

In Indonesia, *Anopheles balabacensis* may be sympatric with other malaria vectors. In Central Java, for instance, a persistent focus of malaria was attributed to the rice field breeding *A. aconitus*. In this area of Banjarnegera residency, however, the local fruit salak is grown in plantations and fruit collectors work at night to get the fruit to the markets early morning. Research by the Vector Control Research Station in Salatiga (Director: Dr Sustriayu Nalim) indicated that malaria transmission occurs in the forested environment by *A. balabacensis*.

In resettlement projects, those communities living on the forest fringe are often at double risk. They will to some extent depend on forest products and will therefore be exposed to transmission risks by *A. dirus*, and at the same time they may be at risk of disease transmission associated with their agricultural activities or their settlements. Forest fringe rice growers in Thailand may therefore be at an increased risk of malaria and of Japanese encephalitis.

Irrigated rice fields make up the largest man-made wetlands environment in the world. Of the 150 million hectares of the global harvested rice area, about 77 million hectares are irrigated; of the total hectarage, 95% can be found in developing countries.

A flooded rice field is an agroecosystem that is frequently disturbed by farming practices, i.e. tillages, irrigation, fertilization, crop establishment and weeding, as well as by natural
phenomena such as rainfall and flooding, which result in extreme instability on a short time scale during the crop cycle, but relative stability on a long time scale.

Flooded rice fields are eutrophic systems with exceedingly high recycling rates of nutrients and energy, as exemplified by the rapid succession of algae. The ecology of rice environments exhibits enormous spatial variation due to extremes in climatic, soil and hydrological conditions under which the crop is grown. The predominant role of water depth and dependability of the flooding regime in delineating rice environments is well recognized. Current terminology considers five dominant environments based on the maximum sustained depth of water in the field:

- irrigated with controlled shallow water depth (5-10 cm)
- rainfed lowland, with uncontrolled shallow water depth (1-50 cm)
- deep water, with maximum sustained depths from 50 to 100 cm
- very deep water, more than 100 cm deep, and
- upland, with no surface flooding
The association between irrigated rice production systems and vector-borne diseases is the subject of extensive literature. In general, Asian rice fields may breed very specific species in well defined areas. These include Anopheles culicifacies in India, A. aconitus in Indonesia and A. maculatus in Nepal. In terms of health impact, however, none of these vectors can compete with the forest breeding A. dirus group. Also, technically, a clear distinction should be made between those vectors that exclusively breed in rice fields and those that breed in irrigation schemes at large, including ancillary structures such as irrigation or drainage canals.

Slide C.14 shows ideal conditions for the breeding of A. maculatus in Nepal, where rice is grown on irrigated hillsides, providing many small pools and seepages. When the paddy is flooded, cattle may be taken to pasture elsewhere, thus reducing the availability of animals as a source of blood meals. This, in turn, may cause the so-called anthropophilic index to rise, i.e. higher proportions of mosquitoes will bite humans instead of cattle. These events will coincide with the time of the year when rainy and warm weather gives rise to higher densities of A. maculatus. Malaria transmission is likely to increase due to a combination of these conditions.

In Africa, the range of breeding habitats of the A. gambiae complex is so broad and transmission so intense that it is hard to determine to which proportion malaria can be attributed to irrigated rice production systems. Extensive research by Lindsay in the Gambia, by Carnevale in Burkina Faso and by Coosemans in Burundi has revealed more detailed information, but has also raised new questions. Unlike the Asian situation, in Africa mosquito density is not linearly correlated to transmission intensity - on the contrary, where irrigation development has led to an increase in the density of mosquito populations, transmission levels have frequently decreased.

In order to further clarify the various phenomena of irrigated rice associated malaria, the West Africa Rice Development Association, together with PEEM and IDRC/Canada, initiated, in 1995, a consortium research project on the association between irrigated rice production and vector-borne diseases in West Africa, with support from IDRC, DANIDA and the Government of Norway. The contact person is Dr Thomas Teuscher at WARDA in Bouaké, Côte d’Ivoire (see list of PEEM collaborating centres).
References


Slide C.16

Slide C.17

Slide C.18

Malaria vectors in Africa belonging to the *Anopheles gambiae* complex are among the most versatile in terms of breeding habitats. In slide C.15 the role of irrigated rice fields is already highlighted, where, as a rule, species succession takes place as the crop develops. But *A. gambiae* breeds in other, sunlit water collections as well. The crucial issue is the lifespan of pools after rainfall: do they last long enough for the almost two weeks needed for an *Anopheles* larva to complete its development? Water collections can be of many types: they can be pools near villages, but they can be as small as animal hoofprints. Collections for drinking water or for irrigation purposes can also contribute significantly to the mosquito population. Water collections in human settlements (for instance, roof tank) ensure that transmission takes place in villages, peri-urban areas and in urban areas. The importance of urban agriculture in this connection has not been the subject of detailed studies, but where this leads to clean,
fresh water collections within the city boundaries, it will certainly play a significant role in urban malaria.

Perhaps for more than any of the other malaria vectors, the proper identification of \textit{A. gambiae} and the design of control measures requires the involvement of a \textit{medical entomologist}. Most ministries of health have a vector control department with the appropriate expertise.

The WHO Offset publication 66, Environmental Management for Mosquito Control (see bibliography) contains, in annex 1, a complete overview of malaria vector species and their ecological requirements is given. This overview is also presented in the VBC slide set Environmental Management for Vector Control.

\textbf{Slide C.19}

Natural or man-made cascades, such as weirs and spillways provide potential breeding sites for simuliid blackflies. Exposed rocks in rivers and streams with turbulent flow create a habitat suited to the breeding of simuliid black flies as well: aerated conditions that are essential for the development of larvae and pupae.

\textbf{Slide C.20}

\textbf{Slide C.21}

\textbf{Slide C.22}

\textbf{Slide C.23}

\textbf{Slide C.24}

The general type of ecology favouring sandflies is the arid shrubland shown on this series of slides. Around the Mediterranean, several \textit{Lesihmania} vectors occur: \textit{Phlebotomus ariasi} is important in the wooded hills of South West France, where infected hogs serve as the reservoir for this zoonosis (C.20). The phenomenon of aggravated leishmaniasis in AIDS patients has become of increased public health importance.

In Kenya, Kala-azar, the visceral form of leishmaniasis, is found in the northern, semi arid zones: slide C.21 shows the rich clopes with bands of cliffs where a close contact exists between the human populations, the sandflies and the local reservoir, rock hyraxes. In northern Kenya the vector \textit{P. martini} is commonly found in large numbers in termite hills.

In the then Soviet Republic of Uzbekistan, land preparation with agricultural machinery was used to destroy the rodent habitat, eliminating both the habitats of the vector and of the reservoir host.