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ON ENVIRONMENTAL MANAGEMENT FOR VECTOR CONTROL

TRAINING AIDS FOR LECTURES ON

ENVIRONMENTAL MANAGEMENT FOR VECTOR CONTROL

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PREFACE

The last ten years have seen a renewed interest in the use of environmental management as part of an integrated approach toward disease vector control. This interest has originated in part from a growing concern about the possible adverse health impacts of the continued development of water resources. However, problems such as insecticide resistance and waning public acceptance of house-spraying campaigns have increasingly impaired chemical control, thus also contributing to the revival of environmental management.

Visual training aids on environmental management for vector control have been badly needed for several years now as a tool in conducting seminars on prevention and control of water-associated vector-borne diseases in water resource development projects and in training courses on vector-borne disease control.

Since 1981 a Panel of Experts on Environmental Management for Vector Control (PEEM), which was jointly established by WHO, FAO and UNEP has been promoting environmental management methods.The Institute of Land Improvement and Water Management, part of the Swiss Federal Institute of Technology (ETH-Zurich), which has been designated a WHO/FAO/UNEP Collaborating Centre on Environmental Management for Vector Control, has used material collected for a seminar on vector control in Zurich in preparing this set of training aids.

SCOPE AND TARGET AUDIENCE

This set of training aids provides an introduction to the role of water resource management schemes in spreading a number of important communicable diseases of man. It limits itself to those diseases which are transmitted by invertebrate organisms whose lifecycle, either partly or wholy, is associated with the aquatic environment. These organisms can be flying insects, in which case they are called *disease vectors* , or certain species of snails, known as *intermediate hosts.* For practical purposes, in this brochure reference will be made to "***vectors***" on the understanding that this term includes the snail intermediate hosts of schistosomiasis. It presents a number of adverse conditions as they frequently occur in water resources development projects, followed by examples of environmental engineering measures which can be applied for their correction.

These training aids are first of all aimed at *engineers,* who are, or will be, responsible for the design and construction of irrigation and other hydraulic projects. However they are also designed to serve as part of a package of educational material for the training of *vector control specialists.* They will hopefully contribute to a better, mutual understanding and collaboration between these two groups.

HOW TO USE THE TRAINING AIDS

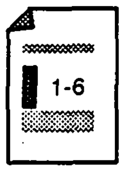
The brochure of the training aids contains four parts, and the first three (A, B and C) are accompanied by overhead transparencies and slides; part D constitutes the didactic material, which may be copied and distributed to the audience as hand outs. Part D1 contains the entire text of this brochure, part

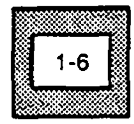
D2 is a summary, containing only figures and tables.

PART A: Introduction

- water related diseases and their public health importance *page 4*

6 overhead transparencies — 6 slides

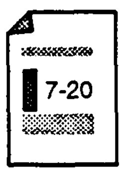


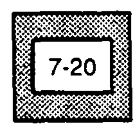


PART B: Water-associated vector-borne diseases, with the emphasis on the vector

- water based diseases *page 8*
- water-related vector-borne diseases *page 12*

14 overhead transparencies — 14 slides

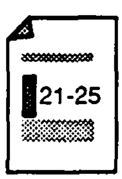


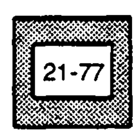


PART C: Negative health effects of water resource projects and environmental management measures for their control

- water offtakes and intakes *page 20*
- impoundments *page 20*
- irrigation methods *page 21*
- irrigation and drainage canals *page 24*
- project ancillary structures *page 25*

5 overhead transparencies — 57 slides





PART D: Appendix

- didactic material
- additional reading list
- glossary (health/engineering)
- basic information on mosquito vectors and diseases
- list of slides, and their captions

The lecture material will take approximately ***four hours*** to cover (two hours for part A and B, and two hours for part C). ***However it may be extended by the lecturer emphasising different aspects of the course, depending on the audience and the priorities of the course.*** Subject to the circumstances, the lecturer may use the blackboard instead of the overhead tranparencies. Overhead transparencies have been copied on slides as well, for the case that no overhead projector is available.

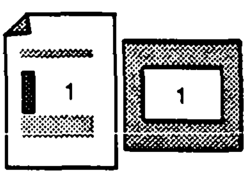
PART A: INTRODUCTION

WATER-RELATED DISEASES AND THEIR IMPORTANCE

Water may carry causative agents (pathogens) of communicable diseases of man or provide the right environment for the breeding and propagation of their vectors. Irrigation and drainage projects create great expanses of water and, provided a number of ecological conditions are met, will thus lead to the introduction of disease vectors in areas where they did not occur before, or to a rapid increase of their original densities. Wherever a parasite or another disease causing organism is present, and a susceptible human population exists, environmental changes resulting from such projects may have a profound impact on the epidemiology of disease through their effect on vector bionomics. In addition, sometimes the disease agent is introduced by human migration resulting directly from project development.

Disease transmission may be particularly rapid in densely populated areas associated with irrigated lands. The adverse effects of irrigation may be related to overrights at the initial planning and construction of the system, or to its mismanagement in the operational phase. Water related diseases may be avoided or alleviated by good engineering practice and by appropriate water management.

Water related diseases can be classified into 4 major categories, as follows:



1: Water-borne diseases:	infections spread through contaminated drinking water
2: Water-washed diseases:	diseases due to the lack of proper sanitation and hygiene
3: Water-based diseases:	infections transmitted through an aquatic invertebrate organism
4: Water-related vector-borne diseases	diseases transmitted by insects that depend on water for their propagation

Table 1: SOME WATER RELATED DISEASES AND THEIR IMPORTANCE

Disease group	*Disease*	*Estimated infection rate (1'000/year)*	*Estimated morbidity (1'000/year)*	*Estimated mortality (1'000/year)*
WATER-BORNE DISEASES	Diarrhoeal Diseases	not available	1'000'000 [1)]	5'000 [1)]
	Typhoid Fever	1'000	500	25
WATER-WASHED DISEASES	Ascariasis (=roundworm infection)	800'000-1000'000	1'000	20
	Ancylostomiasis (=hookworm infection)	700'000-900'000	1'500	50-60
WATER-BASED DISEASES	Schistosomiasis (Bilharzia)	200'000	?	500-1'000
WATER-RELATED VECTOR-BORNE DISEASES	Malaria	240'000	100'000	not available
	Lymphatic filariasis	90'200	2'000-3'000	low
	Onchocerciasis	17'800	340	20-50
	Japanese encephalitis	not available	20-40	case fatality ratio between 10-30%

1) Children under 5 years of age in the developing countries, excluding China
Based on WHO/HST/87.3: Global estimates relating to the health situation and trend, May 1987

This classification relates to the following conditions which characterize the situation in most developing countries and are responsible for the continued high prevalence of these diseases:

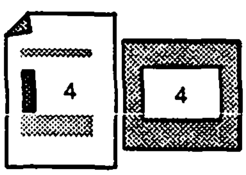
a) **Insufficient water supplies and sanitation, as well as solid waste disposal services are important factors leading to the spread of many of the diseases**: The presence of adequate quantities of good quality water is a prerequisite for satisfactory personal and domestic hygiene. The installation of sanitation and waste disposal measures are similarly essential if the standard of living is to rise for the population of an economically successful irrigation scheme. The introduction of a public health component at this stage *involves only a relatively small increase in the overall cost of the project*, much less than that of remedial operations which may have to be undertaken later in the absence of proper initial planning.

b) **Inadequate housing and lack of hygienic conditions**: The improvement of housing and hygienic conditions is mainly achieved through *education, demonstration, and economic changes*. For example, latrines have to be built, maintained and ***used.*** To reduce man-pathogen contact, in the case of schistosomiasis settlements should be sited sufficiently far away to discourage the use of the irrigation canal and reservoir water as the main water supply for a community and another suitable source of water should be provided. Such siting can also serve to reduce man-vector contact, if housing is at a distance from vector breeding places beyond the flight range of mosquitoess. Screening of houses with wiremesh gauze may give protection to the occupants.

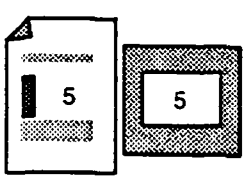
c) **Lack of good health care**: For economic, managerial or technical reasons health care may be inadequate for the proper treatment of infected people and, where vaccines exist, for the organization of immunization campaigns. Attention should be given to vaccination of young children who are particularly vulnerable. Preventive medicine measures in addition to curative medicine, should be promoted whenever possible.

d) **Water resource management schemes**: Water resource development projects such as irrigation schemes often contribute to water related diseases, by increasing the number of vector habitats. Impoundment projects may reduce or eliminate some vector habitats, e.g. those of the black fly vectors of onchocerciasis. Two major diseases which need to be considered are malaria and schistosomiasis in habitats created by water development projects. Chemical methods directed against vectors or intermediate hosts may become necessary for their control: insecticides against mosquito vectors of malaria or molluscicides against the snail intermediate hosts of schistosomiasis. Planning and designing for good water management structures may avoid problems of mosquito vectors and intermediate host snails at the same time; insecticide resistance will no longer be a concern.

The water based and water related diseases which will be covered in the following sections of the training aids can be defined as those diseases where environmental health engineering seeks to modify and manipulate the environment in such a way as to prevent or reduce the transmission.



Hydraulic engineering is an important component of environmental management in which relevant activities include *drainage, stream canalization, lining of streams and canals, land levelling and filling to eliminate depression areas, seepage control, piped or covered canals and drains, weed control, improved water management, diking and dewatering, and* ***strict discipline in the use of water.*** These measures promote community health and contribute to its economic development. As a rule, no single method used by itself is sufficient to prevent occurrence of any or all of the listed diseases. An ***integrated control approach is needed, if permanent results are to be achieved.*** Integrated control must include good planning of environmental management methods, combined with, whenever appropriate, chemical and biological control measures.

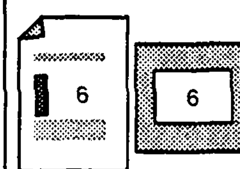


The ***objective*** of environmental management for vector control is the ***reduction of the population density of target species below disease transmission threshold levels.*** Past experience with disease vectors has shown that each species has a defined geographical distribution and occurs in large numbers only when breeding sites with optimal physical, chemical and biological conditions exist. Environmental management measures depend on a thorough understanding of ***vector ecology*** and population dynamics as well as understanding ***vector-borne disease epidemiology***.

Table 2: ASSOCIATION BETWEEN VECTORS, THEIR HABITAT AND THE PRINCIPLE DISEASES THEY TRANSMITT

			Culicine mosquitoes	Anopheline mosquitoes	Simuliid blackflies	Oncomelania snails	Biomphalaria snails	Bulinus snails
DISEASE	**Arbovirus Diseases:**	Dengue	●					
		Yellow fever	●					
		Japanese encephalitis	●					
	Filariasis:	Bancroftian	●	●				
		Brugian	●					
		Onchocerciasis			●			
	Malaria:			●				
	Schisto-somiasis:	mansoni					●	
		haematobium						●
		japonicum				●		
RELATION TO WATER	immature stages live in water		●	●	●			
	lives near water		●	●	●	●		
	entire lifecycle in water		●			●	●	●
PREFFERED HABITAT	rain forests		●	●				
	riverian vegetation			●				
	irrigation ditches and canals		●	●		●	●	●
	lakes and ponds			●		●	●	●
	wetland rice cultivation			●		●	●	●
	rivers and streams			●	●	●	●	●
	human settlements		●	●			●	●
	coastel plains		●	●				

adapted from: Guidelines for forecasting the vector-borne disease implications in the development of a water resource project (preliminary draft version), VBC 186.3, WHO, Geneva



PART B

WATER-BASED AND WATER-RELATED, VECTOR-BORNE DISEASES WITH EMPHASIS ON THE VECTOR

1. WATER-BASED DISEASES: Infections with parasites, for which aquatic and semi-aquatic snails function as intermediate hosts.

In this group ***Schistosomiasis*** is the only disease that will be discussed. It has a wide distribution and there are an estimated 200 million people infected in tropical areas.

There are two forms of the disease depending on the parasite species involved; one affects mainly the **intestinal tract** and the other affects the **urinary system**. *Schistosoma* parasites are trematode worms, or blood flukes, whose adult stage lives in specific veins in its principal host. They have to spend part of their lifecycle in certain species or species groups of snails.

The intestinal form is caused by *Schistosoma mansoni, S. japonicum*, or, of much more limited importance, by *S. intercalatum*. ***S. mansoni*** is found in Africa, parts of the Caribbean and in some northern and eastern parts of South America. Snails of the genus *Biomphalaria* are the intermediate hosts of *S. mansoni*. ***S. japonicum*** occurs in the Far East and is transmitted by snails of the genus *Oncomelania*.

S. haematobium, which invades the veins around the urinary tract, occurs in Africa and the Middle East and is transmitted by snails of the genus *Bulinus*.

Figure 1: GEOGRAPHICAL DISTRIBUTION OF SCHISTOSOMIASIS MANSONI AND S. INTERCALATUM (Source: WHO)

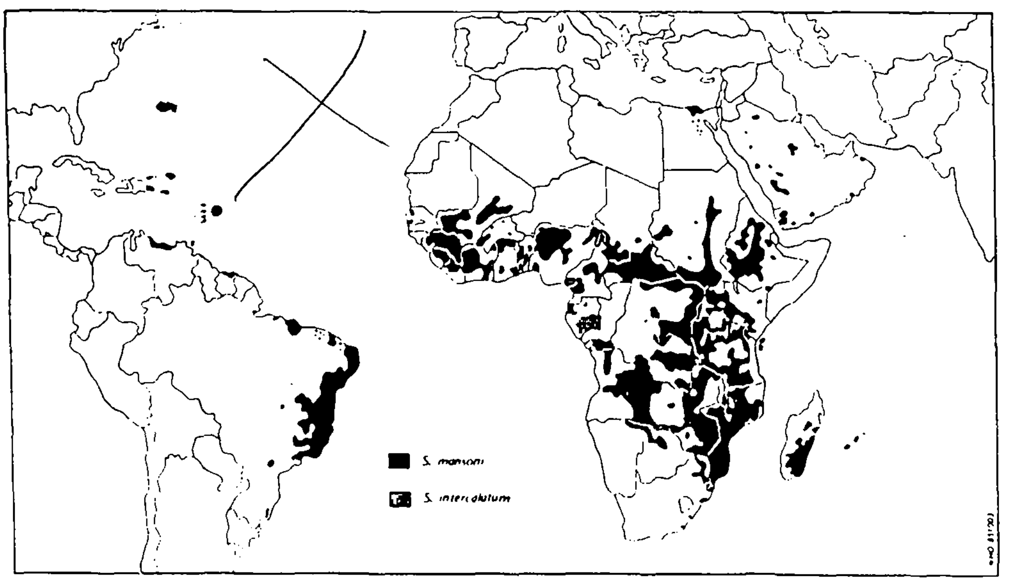
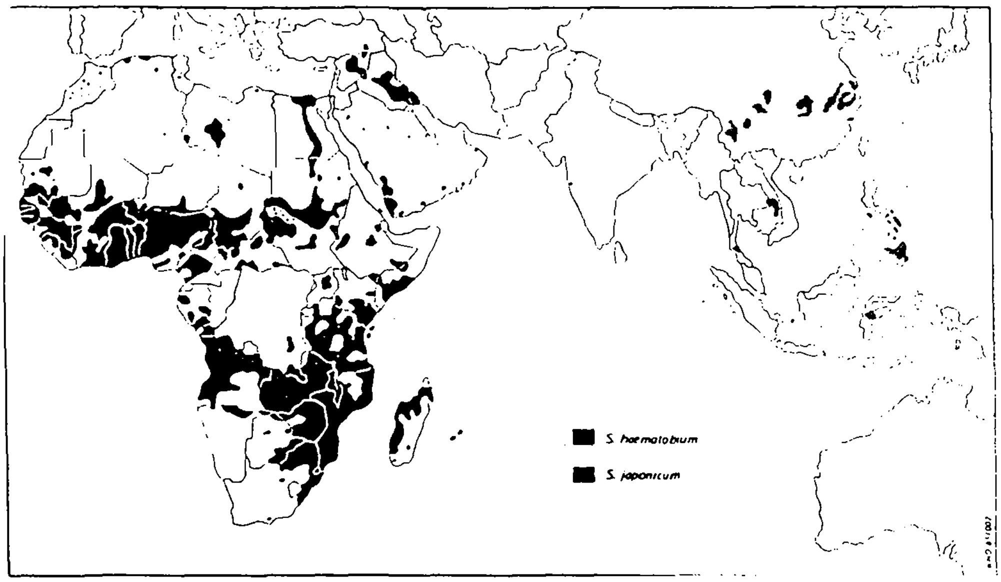


Figure 2: GEOGRAPHICAL DISTRIBUTION OF SCHISTOSOMIASIS HAEMATOBIUM AND S. JAPONICUM (Source: WHO 1987)



All of the above mentioned snail species are found in fresh water, *Oncomelania* is unique in being semi-aquatic. It leaves the water and can be found in considerable numbers on moist ground. Each of the genera (*Biomphalaria, Oncomelania, Bulinus*) contains a number of species of snails (about 20 in each genus). *Schistosoma mekongi*, although a rare parasite, may eventually become of some significance in relation to water development in the Mekong Valley.

Table 3: THE PRINCIPAL GENERA OF SNAILS AND THE PRINCIPAL FORM OF SCHISTOSOMIASIS WHICH THEY TRANSMIT

SNAIL GENUS	LIFECYCLE	PARASITE	TYPE OF DISEASE
Oncomelania	semi-aquatic	S. Japonicum	intestinal
Biomphalaria	aquatic	S. mansoni	intestinal
Bulinus	aquatic	S. haematobium	urinary

1.1 The life cycle of a Schistosome (S. mansoni as an example)

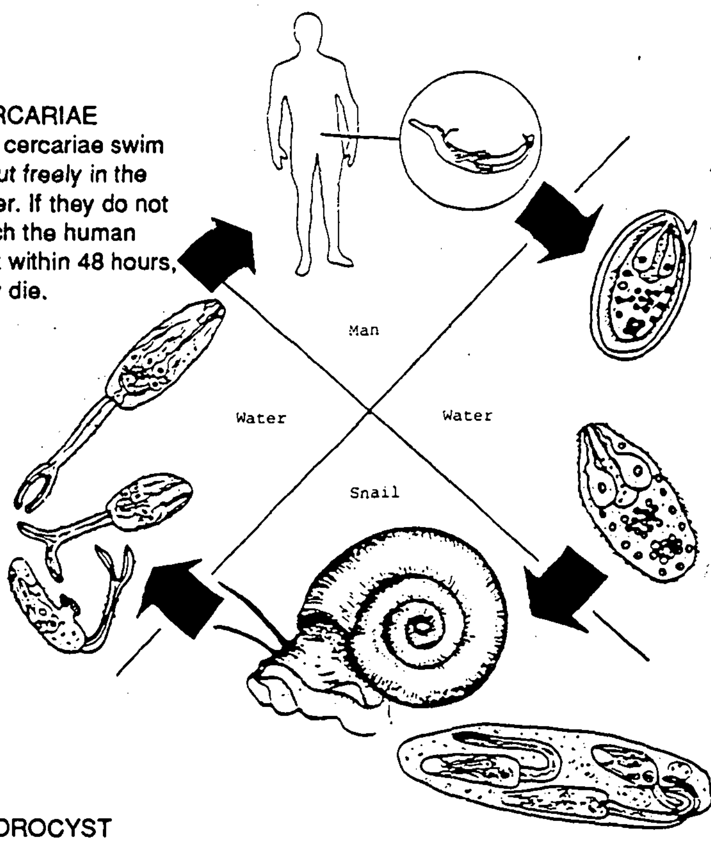
The means by which humans become infected with schistosome parasites (also called flukes) is one of natures complex biological systems. Eggs containing the schistosome larvae are passed with the urine or faeces of an infected person into the water. Because of the change of the osmotic pressure in the water, the eggs rupture and the larva (called miracidium) hatches from the egg. The miracidium must enter an aquatic (or amphibious) snail within about 6 to 24 hours, or it will die. Once in the snail, the miracidium develops into another stage called a sporocyst. During a period of 4 to 8 weeks (in Oncomelania the time may exceed 8 weeks), fork-tailed cercariae develop within the sporocysts, and these eventually leave the snail host. After leaving the snail, the cercariae swim about freely in the water in search of a vertebrate host. **Unless they are able to contact and enter a vertebrate within 24 to 48 hours, they die in the water.**

Figure 3: THE LIFECYCLE OF A SCHISTOSOME

ADULT WORMS
Adult worms live inside human veins. The inset illustration shows the fatte r male worm holding the thinner female wom within the fold in his body wall.

CERCARIAE
The cercariae swim about freely in the water. If they do not reach the human host within 48 hours, they die.

EGGS
Eggs contain the larvae which are passed with the urine and faeces of an infected person



MIRACIDIUM
The miracidium larva hatches from the egg in water. After a free life of about six hours it seeks out and enters an aquatic snail

SPOROCYST
The miracidium develops into a sporocyst. After a time, fork-tailed larvae or cercariae are produced within the sporocysts, from which they ultima tly break out.

Source: Dr. J.M. Jewxbury in: Irrigation and Dams, their Impact on Public Health; Silsoe, June 82

For two species, *S.haematobium* and *S. mansoni,* the principle host mostly is human, while *S. japonicum* also infects domestic animals such as water buffaloes, dogs, cats, pigs and rodents. On penetrating the peripheral veins of the host, the cercariae develop into adult parasites. After mating, males and females live togehter as pairs; the bigger male worm holding the smaller female worm within a fold of its body.

To interrupt the lifecycle of schistosoma parasites, the man-water contact has to be minimized, no faeces or urine should enter the water, or the number of snails has to be diminished. Chemotherapy, which reduces or eliminates the parasite in man, is another approach to interruption of the life cycle.

1.2 Bionomics of snail intermediate hosts

Physical factors: Snails tolerate temperatures from 18° to 32°C and develop best at a temperature of 26°C. As a rule, ***snails do not tolerate water velocities higher than 0.7 m/s,*** nor turbulences and waves, and seldom are found in water depths greater than 1.5 m.

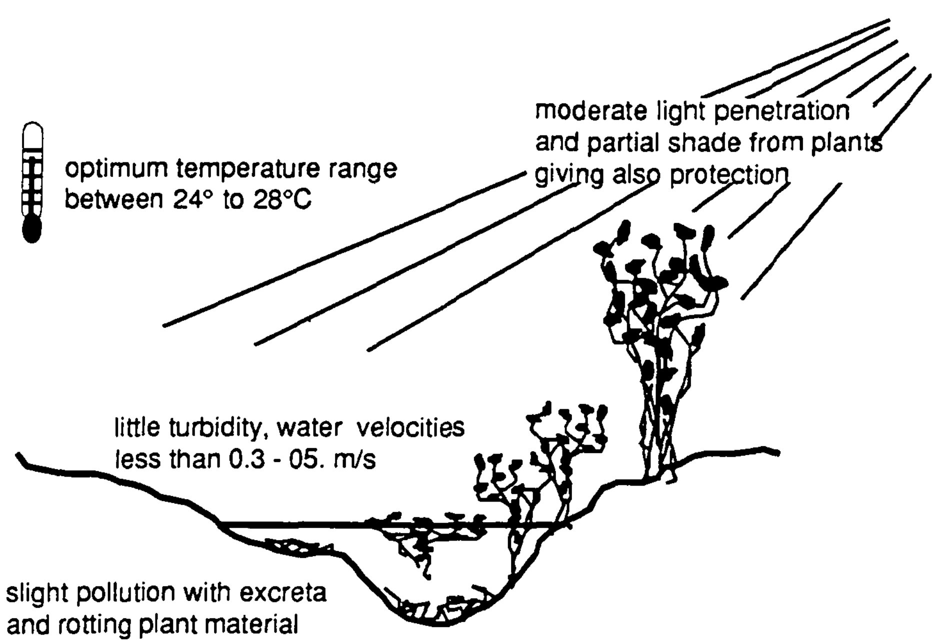
Some snail species are adapted to the drying-up of water bodies. Such snails may survive where water is present for only three months in the year. Species of *Oncomelania* are semi-aquatic and can survive in marshes. They are well adapted to irrigation systems, rice fields, and especially to drainage canals and ditches.

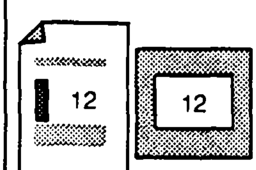
Biological factors: Snails have ***few natural enemies*** . They frequently attach to relatively dense vegetation and to ***plants giving protection from direct sunlight and water current.*** Snails are omnivorous animals and prefer rotting plant material (unicellular green algae is preferred fodder). Aquatic weeds have an important role with respect to the oviposition by snails.

Chemical factors: Snails are very tolerant to dissolved matter in water including chlorides, minerals and salt. They may be found in waters of a wide range of pH values (5 to 10). However, water containing barium, nickel or zinc is toxic for snails.

Water contamination: ***Moderately polluted water*** with faecal and/or organic plant material is ***most favourable*** for the development of snails.

Figure 4: FAVOURABLE HABITAT REQUIREMENTS FOR AQUATIC SNAILS (also preferred by the amphibious species)



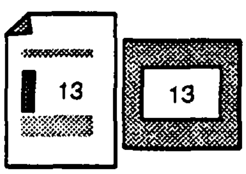


2. VECTOR-BORNE DISEASES: Transmission by insects having aquatic immature stages

2.1 Mosquitoe-borne diseases

Mosquitoes have a cosmopolitan distribution. The number of species exceeds 3000. Mosquitoes have been classified into three subfamilies - ***ANOPHELINAE, CULICINAE*** *and* ***TOXORHYNCHITINAE.*** The latter subfamily does not include vectors of disease and is not discussed here.

Five of the major vector-borne diseases *transmitted by the female mosquito* while obtaining a blood meal, necessary for the development of their eggs, are presented below. Only malaria, brugian filariasis and japanese encephalitis are of direct relevance in irrigation projects. The vectors of yellow fever and dengue fever breed in the environment of human settlements. These diseases may therefore be indirectly related to irrigation development.



1. MALARIA: Although there are more than 400 known species of *anopheline* mosquitoes, only about 30 species can be considered important *malaria vectors. Only the female mosquito obtains blood meals. Its ability* to be an efficient vector is related to its contact with man. Malaria is responsible for high morbidity and mortality rates in the tropical and subtropical areas of the world, especially in the young age groups. Malaria debilitating effects and general impairment of well-being, resulting from the accumulated effects of repeated infections, are a great concern, because they hinder the economic and social progress of the regions where this disease is widespread.

2. FILARIASIS: Mosquito-borne filariasis in man includes a group of diseases caused by parasitic worms called filarial nematodes. The species of *filarial worms involved are Wuchereria bancrofti, Brugia malayi* and *B.timori. Wuchereria bancrofti* has an extensive geographical distribution and is found in many tropical countries. Several genera and species of mosquitoes are vectors of filariasis. *Culex quinquefasciatus* is a mosquito found primarily in urban and suburban areas. *Anopheles, Mansonia* and *Aedes* species also can serve as vectors for filarial nematodes.

3. JAPANESE ENCEPHALITIS is an acute, often fatal disease caused by an arbovirus (arthropod-borne virus). Patients suffer from fever, may become comatose and die of encephalitis. Recovery often leaves neural *impairment. The disease is widely associated with Culex tritaenior hynchus* or *Culex gelidus* mosquitoes throughout Asia, north from India and particularly with ricefields where the mosquitoes thrive. Several vaccines are available.

4. YELLOW FEVER is an acute, often fatal disease caused by an arbovirus (arthropod-borne virus). The urban type of yellow fever is transmitted by Aedes aegypti mosquitoes whereas other genera and species of mosquitoes may be involved with jungle yellow fever. Mosquitoes of the genera Haemagogus and Sabethes are vectors of jungle yellow fever in the Americas but species of Aedes are vectors in Africa. Yellow fever has not been found in Asia.

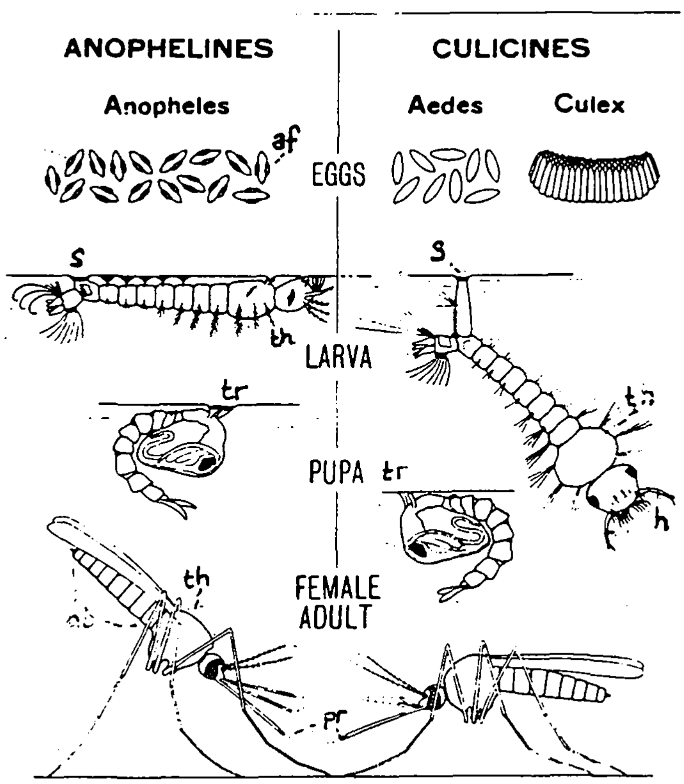
The development of effective vaccines and their mass application have reduced the occurrence of yellow fever, and it no longer has the global importance it had half a century ago. However, occasional cases and sporadic epidemics still occur in Africa and South America.

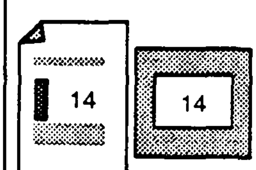
5. DENGUE FEVER, widespread in 60 tropical/subtropical countries, is an acute febrile disease with a low mortality rate, characterized by fever, intense muscular and joint pains, and prolonged incapacitation. The causative agent is a virus related to yellow fever. It is transmitted primarily by *Aedes aegypti*, a container breeding mosquito, that is closely associated with man and urban development. However, other *Aedes* species also may be involved. A more severe disease, dengue haemorrhagic fever, has produced high mortaility among children in SE-Asia and 1981 reached the Caribbean region with outbreakes in Cuba (1981), Mexico (1985) and Puerto Rico (1986). No vaccine is available as yet.

2.1.2 The life cycle of a mosquito (adapted from WHO Offset publ. No. 66)

The immature and adult stages of mosquitoes are passed in two completely different environments. The immature stage, i.e., eggs, larvae and pupae, require an aquatic environment, and the adult mosquito requires a terrestrial one.

Figure 5: CHIEF DISTINGUISHING FEATURES OF ANOPHELINES AND CULICINES (source WHO publ. No. 66)





Egg: *Anophelines* lay their eggs separately on the surface of water, and each egg has lateral air floats (**af**) to keep it afloat. *Culicines* of the genus *Culex* and *Coquilletidia* lay several eggs cemented together as an egg raft on the water; whereas, those of the genus *Aedes* are laid separately, often in **dry hollows** or **containers** which become flooded after rain. The eggs of many *Aedes* species are able to retain their viability without water for long periods.

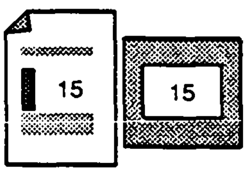
Larva: Eggs of mosquitoes generally ***hatch after two or three days in contact with water.*** Some transient pool or floodwater species, e.g., *Aedes*, may hatch within half an hour of submersion in water. The larva of most species is about 1.5 mm long when newly hatched and about 10 mm long when fully grown. The larvae cast their skins four times, as they grow into larger stages. The larva of a mosquito has a head (**h**), thorax (**th**) and abdomen (**ab**) - the latter having eight distinct segments. A mosquito larva breathes through a pair of orifices at the terminal end of the body called spiracles; those of the anopheline larvae are situated on the eight abdominal segment so that, in breathing, it rests in a horizontal position at the surface ot the water.

In *culicine* larva, the spiracles are situated at the end of a tubular organ, called the siphon (**s**), which extends from the eighth abdominal segment. The *culicine* larva hangs down from the water surface by the tip of its siphon in order to breathe. An exception is the genus *Mansonia,* in which the siphon is highly modified for piercing and adhering to stems of aquatic plants from which air is drawn for breathing.

Pupa: The pupa is a non-feeding stage, lasting one or more days. This stage provides for the morphological and physiological changes required for transformation of the larva to the adult. The pupa is mobile and able to dive rapidly when disturbed. When quiescent, the pupa rests at the surface of the water. Breathing is carried out, at the surface of the water, by a pair of respiratory trumpets (**tr**) extending from the thoracic area.

Adult: After emergence (5 to 10 days after the eggs have been laid), the adult mosquito rests for a few minutes on the discarded pupal skin while its wings expand and harden for flight. The proboscis (**pr**) requires longer to harden and is too soft during the first day after emergence for the female to take a blood meal. The adults of both sexes feed on plant juices. Only the female feeds on blood, because egg development is dependent on a blood meal for almost all anophelines and most *culicines.* In a few species the first batch of eggs can be laid without a prior blood meal.

2.1.3 Mosquito bionomics



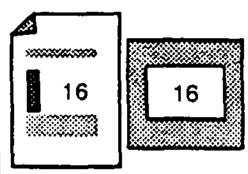
Climatic factors play an important role in species distribution, behaviour, survival, and vectorial capacity. ***Water is an essential component of the mosquito environment. The water habitat, running or standing, clean or polluted, sweet or brackish, shaded or sunlit, permanent or intermittent, is a predominant factor determining which species of mosquito breed in it.*** The environments of the immature stages and the adult mosquito are interdependent, since the adult mosquito must have access to water for egg laying.

Physical factors: Rate of growth of the immature stages of the mosquito depends in part on the temperature of the water. This range is lower for species living in temperate rather than in tropical zones and varies somewhat between different species living in the same geographical zone; thus temperature is one of the limiting factors for geographical distribution of a species. Within these optimal ranges, there is a direct relationship between temperature and growth. For example, ***mosquitoes*** breeding in the tropical zone, in water at 23° - 33°C, ***usually complete their aquatic growth within two weeks.*** Moderately frequent rainfall often increases the opportunities for prolific breeding, but *repeated and heavy rainfall may cause severe flooding and a temporary flushing out of breeding places and reduction in the mosquito population* (except the floodwater complex of mosquitoes). The extent to which the breeding place is shaded or exposed to sun influences which species of mosquito inhabit a particular habitat. Hedges, planted to give shade over breeding places, or clearing of forests to allow sun to penetrate have been successfully used for environmental control of some malaria vectors (*Anopheles minimus* and *A. dirus*).

Biological factors: Unless islands of vegetation are present to provide breeding sites, mosquito larvae are not found on open surfaces of large bodies of deep fresh water (e.g., lakes, ponds, rivers or reservoirs). However, ***Anopheles often are breeding at the sheltered shallow edges of lakes, ponds, rivers, or reservoirs*** . The immature stages of some species (*A. gambiae*) are found throughout the entire surface of shallow swamps and temporary rainwater pools.
The aquatic environment of some species is ***associated with particular plants*** . For example, larvae of *Coquilletidia* (a vector of *Brugia Filariasis)* are linked with the presence of water lettuce plants *(Pistia, Eichornia, Salvinia)* while *Aedes simpsoni* (a vector of sylvatic or jungle yellow fever in Africa) are frequently found breeding in leaf axils of banana plants. Other species such as *A. aegypti*, breed in great numbers in small artificial containers such as old tins, tyres, water storage vessels, flower vases, ant traps, etc.

Water contamination, chemical factors: Some species *(A. funestus)* breed in vegetated clear fresh water, whereas others are adapted to breeding in brackish water *(A. sundaicus)* or highly polluted water *(Culex quinquefasciatus).*
Anopheles gambiae, the main vector of malaria in Africa, develops in different types of breeding sites (i. e., from footprints to ponds, etc.).

Mosquitoes as a group breed in an almost infinite variety of sizes and types of water bodies. *Most disease transmitting species, however, breed only in a restricted narrow range of habitats,* while only few species breed readily in a wide range of habitats.



Some biological insight into the habitats of the vector species in relation to water resources development can help to offset or reduce the disease problem

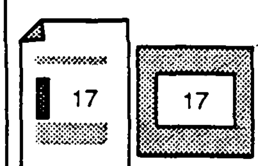


Figure 6: GEOGRAPHICAL DISTRIBUTION OF MALARIA (Source: WHO 87)

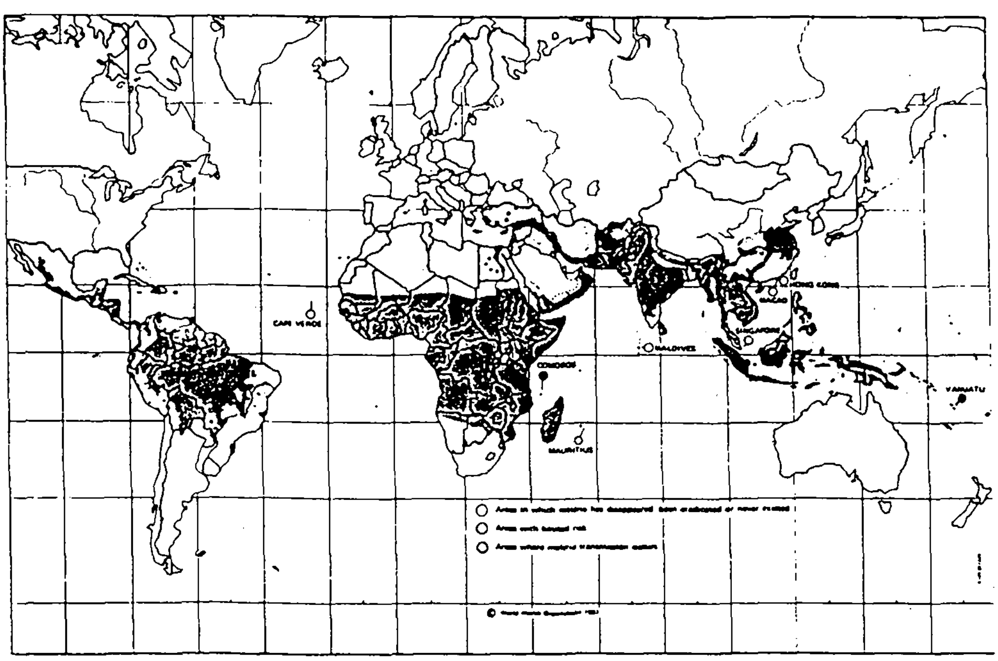
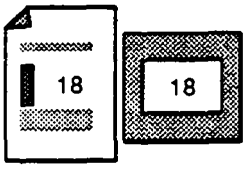
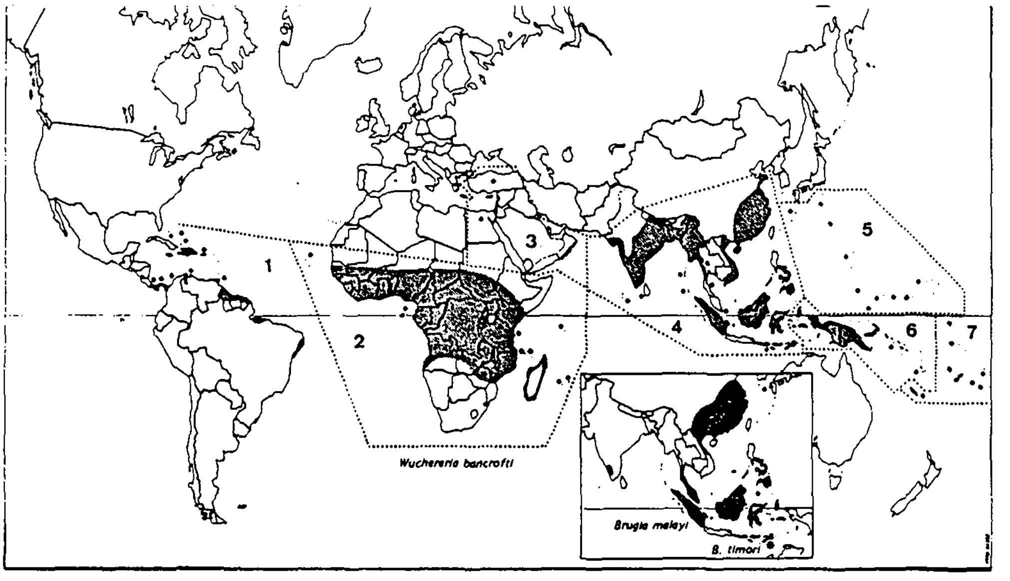


Figure 7: GEOGRAPHICAL DISTRIBUTION OF WUCHERERIA BANCROFTI, BRUGIA MALAYI AND B. TIMORI (Source: WHO 87)

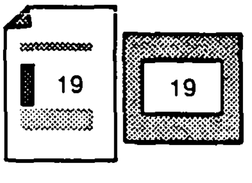


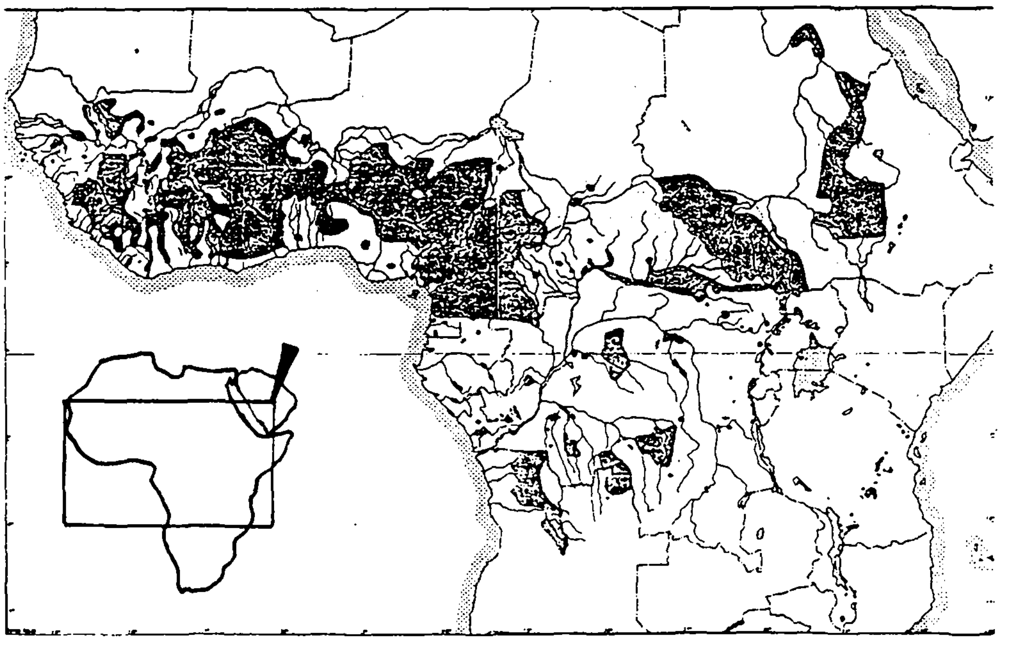


2.2. Blackflies (=*SIMULIUM*)

There are many *Simulium* species, of which the most important is *S. damnosum,* transmitter of ***ONCHOCERCIASIS or "river blindness",*** which is caused by a parasitic worm. Onchocerciasis occurs mainly in tropical Africa, but there are foci of the disease in South and Central America, where other *Simulium* species are the vector. About 18 million people are infected, and some 340'000 have been blinded by the parasite worms causing the disease.

Figure 8: GEOGRAPHICAL DISTRIBUTION OF ONCHOCERCIASIS (source WHO 87)



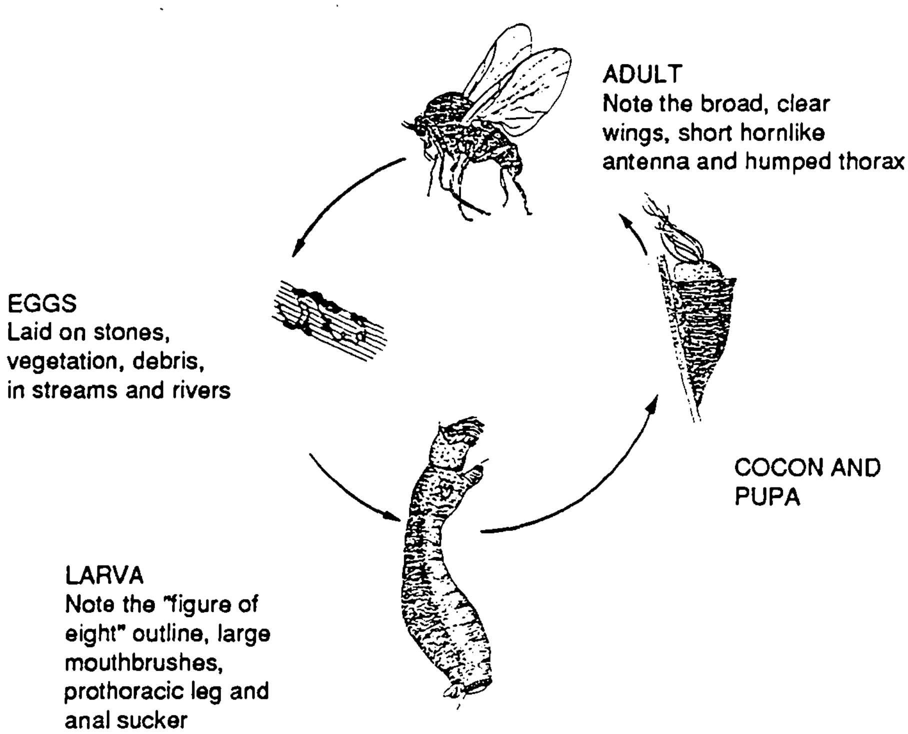


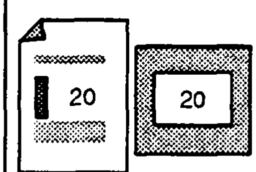
2.2.1 The life cycle of *Simulium damnosum*

The blackfly, like the mosquito, has the ***egg, larva and pupal stages in water,*** but unlike mosquitoes, the habitats are restricted to ***highly oxygenized fast flowing turbulent water,*** containing a readily available source of food. The female black fly lays several hundred eggs, and a blood meal is required before each batch of eggs can develop. Depending upon the temperature, ***development of the larvae takes from 1 week to 15 days.***

The larval stages (called microfilariae) of the parasitic worm *Onchocerca volvulus,* the causal agent of onchocerciasis, is engested by the female blackfly during the blood meal and matures in the fly. At a subsequent meal the matured larvae may be transmitted to a second human host where it develops into an adult worm, mates and produces microfiliarae.

Figure 9: THE LIFECYCLE OF SIMULIUM DAMNOSUM





Source: Dr. J.B. Davies in: Irrigation and Dams, their Impact on Public Health; Silsoe, June 1982

2.2.2 Bionomics of black flies

The main resting places of adult black flies are not well known but females of *S.damnosum* are widespread especially during the rainy season. Their *large flight range (over 15 km) makes control of adults difficult.* Since the larvae are stationary and limited to the turbulent parts of a river they are the easiest to attack with insecticides which can be carried downstream by the water flow. Chemical control treatments have been effective upto distances of 50 km or more (when river discharges were large enough) below the point of larvicide application. The development of larvae resistance to insecticides has diminished the effectiveness of chemical control in some areas. However, *new biological control methods,* such as the use of the bacteria (*Bacillus thuringiensis,* serotype H14) where resistance to the chemical Temephos occurred, *have been successful* in Côte d'Ivoire.

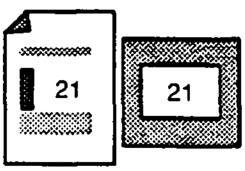
PART C

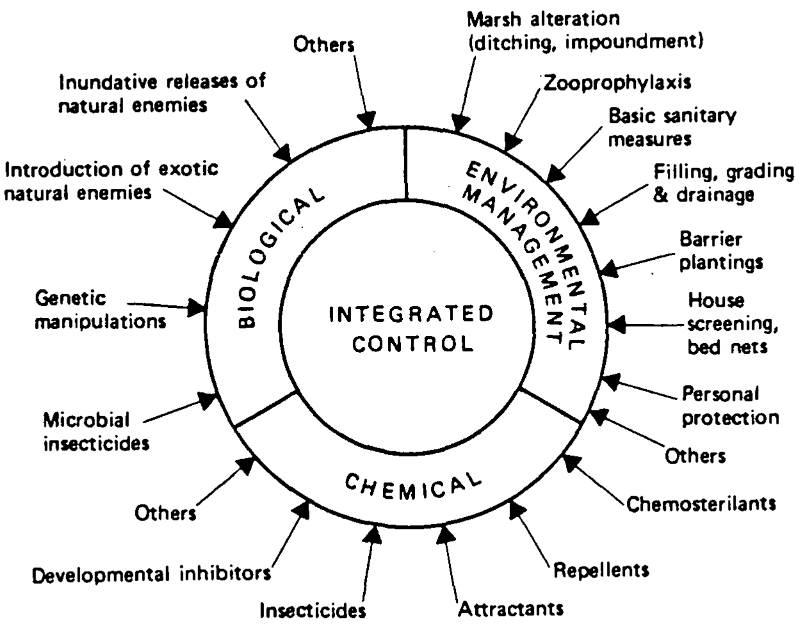
NEGATIVE HEALTH EFFECTS OF WATER RESOURCE PROJECTS AND ENVIRONMENTAL MANAGEMENT MEASURES FOR THEIR CONTROL

Each water resource development project may create its own specific vector-borne disease problems. Therefore, it requires special training, knowledge and experience to determine the potential environmental or health impacts of irrigation, drainage and flood control projects.

By properly planning and managing water resource development projects, the need for special chemical or environmental management methods for vector control later on may be avoided. If the principles of vector control measures are already included in the planning phase, and if the scheme is adequately managed and maintained, there will be no grave adverse health effects on the human population. Where water projects have created vector-borne disease problems it is important to implement the concept of integrated vector control and ensure its conscientious use in the operational phase. This concept is important in all types of water resource developmental projects. The concept of integrated vector control is given in Figure 10:

Figure 10: CONCEPT OF INTEGRATED VECTOR CONTROL

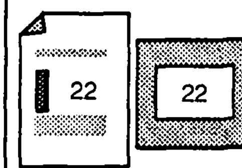




Adapted from: Axtell, R.C. Principles of integrated pest management (IPM) in relation to mosquito control. (Mosquito News, 39: 709-718; 1979)

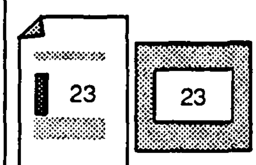
The WHO Expert Committee on Vector Biology and Control in 1979 defined environmental management activities as follows:

Environmental management for vector control: *The planning, organization, carrying out and monitoring of activities for the modification and/or manipulation of environmental factors or their interaction with man with a view to preventing or minimizing vector propagation and reducing man-vector-pathogen contact.*



Environmental management for mosquito control covers a wide range of works and operations which can be further classified and defined: (Source: WHO Technical Report Series, No. 649, 1980.)

a) Environmental modification: "A form of environmental management consisting in any ***physical transformation*** that is ***permanent or long-lasting*** of land, water and vegetation, aimed at preventing, eliminating or reducing the habitats of vectors without causing unduly adverse effects on the quality of the human environment." Environmental modification includes drainage, filling, land levelling and transformation and impoundment margins. Although these works are usually of a permanent nature, proper operation and adequate maintenance are essential for their effective functioning.

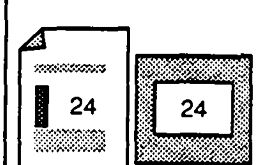


b) Environmental manipulation: "A form of environmental management consisting in any ***planned recurrent activity*** aimed at ***producing temporary conditions*** unfavourable to breeding of vectors in their habitats." Water salinity changes, stream flushing, regulation of the water level in reservoirs, dewatering or flooding of swamps or boggy areas, vegetation removal, shading and exposure to sunlight are examples of environmental manipulation activities.

c) Modification or manipulation of human habitation or behaviour: "A form of environmental management that ***reduces man - vector-pathogen contact.*** " Examples of this kind of approach include the siting of settlements away from vector sources, mosquito proofing of houses, personal protection and hygiene measures against vectors, and provision of such installations as mechanical barriers and facilities for water supply, wastewater and excreta disposal, laundry, bathing and recreation to prevent or discourage human contact with infested waters.

Due to the different behaviour and habitats of vectors, detailed specific investigations are needed to evaluate the potential risks of a water resource development project. Nevertheless two general statements may be given, as many species or larger taxonomic groups have common environmental requirements.

1. Many vectors require an aquatic environment, either in the immature stage (mosquitoes, black flies) or in the immature stages (snails).



2. Aquatic weeds, if not to dense, promote vector development, giving them protection from direct sunlight, natural enemies, wind and water current (except black flies) as well as providing fodder (snails).

Basically all environmental management measures, including the management and maintenance of irrigation, drainage, and flood control projects, may be viewed as follows:

25 25

- **are additional water bodies essential and which are the important water properties (quality, flow velocities)?**
- **How is the micro-climate affected (i.e., raising of humidity and average warm temperature favours vector breeding)?**
- **Which aquatic weeds are involved (in addition to protection, many vectors are associated with specfic weeds)?**
- **What are the consequences on the behaviour of the inhabitants (settlements near impoundments and irrigation channels)?**

It is important to understand the components of an irrigation scheme such as water catchment, impoundment, water distribution, irrigation methods, drainage and settlement of population as discussed below. They are discussed here in relation to their interactions with vector habitats:

1. WATER OFFTAKES AND INTAKES

1.1 Favourable vector habitats

26,27

- pools and puddles created by water seepage and lack of drainage near wells and river catchments.
- the inlet structure of catchments slows down water velocity and may favour weed growth.

1.2 Environmental management measures

28-30

- concrete aprons round the service point with a drain pipe to remove waste water.
- soakaways or seepage pits (holes or trenches in the ground filled with stones through which waste water can seep away into the surrounding soil).
- proper maintenance and weed control.

2. IMPOUNDMENTS (for hydro-electric power, irrigation, flood control, water supply and/or recreation; mostly multi-purpose reservoirs).

2.1 Favourable mosquito habitats

31

It has been observed that in the absence of floating mats of vegetation, *vectors do not breed or live in deep waters (>1.5m) far from the margins of the reservoirs.* Furthermore there is little significant vector breeding along the steep, main shoreline exposed to wave action. ***The impoundment areas subject to vector problems lie within protected hollows, and indentations of the shoreline, where water is usually shallow and contains aquatic vegetation and other floating material.***

- Large impoundments affect the microclimate and produce variations in water temperature which in turn influence mosquito breeding.
- Mosquito population densities may be especially high in reservoirs with small mean depth.
- Frequently human settlements are built near large impoundments, especially when water is scarce. Bathing, fishing, washing clothes, etc. leads to close man/vector contact.

32,33

2.2 Environmental management measures

34

- Reservoir site clearing: Proper preparation of the reservoir site, and in particular removal of trees and other vegetation is needed to ensure a clear water surface at all elevations between high and low operational water levels:
  i) clearing of shoreline subject to erosion,
  ii) clearing at heads of bays and indentations,
  iii) drainage of reservoir margins,
  iiii) deepening and filling: Topographical alteration may be accomplished by a) filling the marginal problem zones to a level above the maximum water level of the impoundment, b) deepening the problem zone to a depth below the lower limit of marginal growth invasion, or c) a combination of a) and b), which normally will be the most economical.
- Water level fluctuation: Any special requirement for this purpose, such as spillway control gates, should be incorporated in the initial dam and reservoir design.
- Maintenance: Development of an ***effective programme for shoreline and drainage maintenance,*** vegetation growth control and drift removal after the reservoir has been filled.
- Resettlement and settlement of population: Depending on the tradition and cultural background of the concerned population, site selection is a primary consideration. Settlement should be located as far away (over 1.5km) from mosquito sources as possible. Sanitary facilities of a standard that ensures protection against disease transmission should be provided and maintained. The provision of facilities in the form of community swimming pools, where it is relatively easy to avoid vectors of disease, would be a relatively small part of the cost of a large irrigation scheme.

35

3. IRRIGATION

In open irrigation canals, water leaving the reservoir, river or pumping station is conveyed along main canals to lateral ones and finally reaches the distribution ditches that supply the cultivated fields. Vector problems can be expected to occur throughout the entire canal complex and will be discussed later. This section deals with problems in the cultivated fields.

36

A number of irrigation methods have been devised to meet particular situations in topography, water supply, crops, customs and agricultural practices. The most common methods are:

Uncontrolled or wild flooding: surface flooding in which water is diverted to non-prepared areas and is let to flow down the natural slopes without controlling its distribution. Also referred to as "mountain flooding".

37

Controlled flooding: surface flooding in which water applied to land is under controlled or guided conditions and it is designated according to the shape or contour of the irrigating unit or according to the method of delivering water to the area within the unit. This includes among others:

- *flooding from ditches* (water flows through irrigation ditch openings or over ditch banks as a sheet across fields),
- *border irrigation* (land is divided into border strips and water is delivered into each strip from a head or field ditch at its upper end),
- 38-41 *check irrigation* (a method of flooding in which the field is divided into a number of checks [level or nearly level areas surrounded by ridges]. If the checks are contour checks [e.g., ridges are approximatly parallel to the contours], the method is called *contour check irrigation*),
- *basin irrigation* (a method of irrigating orchards by which each tree or a group of trees is surrounded by a border, to form a pool or a small basin when water is applied),
- *furrow irrigation* (a method of surface irrigation in which water is run in furrows [narrow ditches] between crop rows),
- *corrugation or rill irrigation* (a method of surface irrigation in which small streams are allowed to flow through a series of narrow, shallow furrows in permeable soil long enough to permit the horizontal seepage from adjacent furrows to meet).

42 **Subirrigation:** watering the plants by applying the water below the ground surface or by effecting the rise of the water table to within or near the root zone.

43 **Sprinkler irrigation:** a method of irrigation in which water (under adequate pressure) is sprinkled over the land through noozle lines, perforated pipes or sprinklers.

44 **Drip irrigation:** application of water to the soil at a very low rate (2 to 10 litres per hour) through small outlets (tricklers or emitters). Water is supplied to the tricklers through polythene pipes under low pressure (1 to 3 atmospheres).

3.1 Favourable vector habitats:

Irrigation methods, especially the ones based on "wild" flooding of land, represent a risk of vector production. The continuous submergence method of rice irrigation is conductive to breeding of a number of disease vectors.

Factors contributing to vector densities are:

- 45-47 pools and puddles due to lack of drainage and/or uneven, unlevelled or badly levelled fields;
- some crops favour mosquito breeding and protect snails;
- manual labour in the fields promotes man/vector contact.

3.2 Environmental management measures

Two precautions should be taken in order to reduce the risk of vector production:

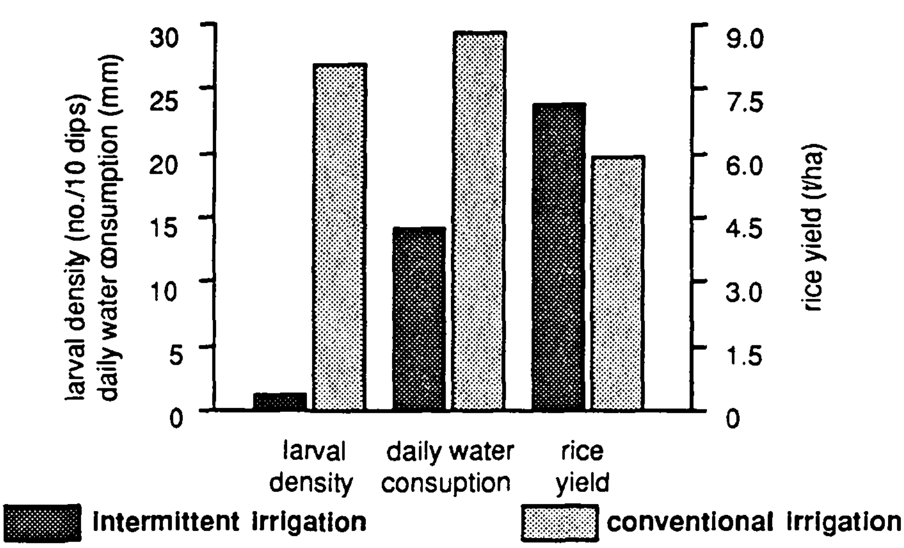
48 a) ***each flood period should last no more than 3 to 4 days. After withdrawal of the water, the areas should be allowed to remain dry for at least one day.***

b) the border strip, contour check or basin should be frequently relevelled and graded to ensure an even and uniform surface that will not produce pools when the flood water is withdrawn. 48

In uncontrolled or "wild" flooding, these two precautions are not observed and this method must be recognized as creating a risk to human health.

- Drainage: The only way to accomplish the rapid withdrawal of water before drying the land is by the provision of properly planned and maintained drainage. 49
- Intermittent rice irrigation: conventional rice irrigation practices usually keep the water in the paddy fields throughout the entire growing period of the plants. The objective of the intermittent method is that, with the exception of the period of seedling transplanting, the water is supplied according to the needs of the plants. During the transplanting period which lasts about 10 - 15 days the fields are filled with water to a depth of 4 to 6 cm. After the plants turn green, contrary to conventional irrigation practice, the water can be drained off. Thereafter the fields are intermittently filled with a shallow layer of water so that it may disappear in 24 to 48 hours through absorption, percolation and evaporation. 50,51
  Typically the interval between two successive irrigations is 5 days or in some cases 3 days. For the entire growing period of about 90 - 130 days for rice plants, the fields are irrigated 21 - 26 times. However such practices may depend on farmer cooperation, the rice strain used and the type of soil.

Figure 11: COMPARISON OF LARVAL DENSITIES, RICE YIELDS AND WATER CONSUMPTION OF INTERMITTENT AND CONVENTIONAL RICE IRRIGATION 52



Source: Ge Fengxiang et al: The study on the control of mosquitoes in the paddy fields by wet irrigation in the alluvial plains of the Yellow River, 1981

As observed in such fields in Japan, mosquito breeding decreased, and, at the same time, the average rice yield increased by 10% as compared with the conventionally irrigated fields.

4. IRRIGATION AND DRAINAGE CANALS

The open canal is a common method for conveying water. Piped systems may be more expensive but are better from the point of view of vector control because they produce virtually no vector breeding or vegetation growth. ***The greatest risk for mosquito production is expected in the minor distribution and drainage channels as they are more suitable for vector production than the larger canals.*** *In addition their maintenance is given less attention, particularly when it is no longer the responsibility of the irrigation authority, and is under the care of the users.* These drainage canals are mostly poorly maintained and they have little direct relationship to increasing the average crop yield, but become excellent mosquito and snail habitats.

4.1 Favourable vector habitats

53-57

Disadvantages of earth canals favouring vectors:

- ❑ water velocities higher than 0.7 m/s are not tolerable because of erosion. The low operating velocities require large cross-sectional areas, thus a wide strip of land is flooded producing many vector habitats.
- ❑ high seepage and conveyance water losses result in waterlogging of adjacent land.
- ❑ danger of canal bank breakage caused by overtopping, erosion and animal burrowing.
- ❑ profuse growth of aquatic weeds retards the flow and causes heavy maintenance costs.
- ❑ Waterflow in drainage ditches is less uniform and constant than in irrigation canals. Choking vegetation and pools of stagnant water causes the waterflow to be even more erratic and more conducive to vector breeding. In these circumstances, problems of silting become more serious than those of erosion.

  These disadvantages may be reduced or overcome by lining earth canals.

- ❑ Due to high costs of a lined canal, often water flowing from the impoundment to the irrigation plot travels several kilometers through a natural stream. The storage regulation causes continous slow to rapid flow, forming backwater pools, marginal pockets and isolated seepage ponds.

4.2 Environmental management measures

58

- ❑ Use of pipes instead of open canals especially for drainage (e.g. burried coconut shells as drainage).

59,60

- ❑ Canal lining: from the viewpoint of vector control, the main advantages of canal lining, especially with a hard surface, are:
  - i) increase of water velocities, thus preventing stagnant or sluggish water. However, this may introduce vectors of onchocerciasis in parts of Africa and S. America,
  - ii) reduction of weeds when properly maintained,
  - iii) reduction of the needs of drains, because seepage is less.

61,62

- ❑ Canal flushing and periodical drying of canal: short periods of increased water velocity may dislodge and expose vectors, stir up bottom sediments burying mosquito larvae, and lowers the invasion of the marginal vegetation that reduces water velocity. This is feasible where there is plenty of water, otherwise might not be advisable.

- Effective canal maintenance to ensure that the canals are in good shape and generally free from vegetation and silting at all times. 63,64
- Resettlement and settlement of population: As not all natural streams and long parent canals may be lined, the same requirements are suggested for the location of settlements and the sanitary facilities as in the "impoundments" section.

5. PROJECT ANCILLARY STRUCTURES

Structures such as road, bridges, dams, weirs, spillways, and siphons always change water velocities locally and therefore may create breeding places for blackflies at the spillway or for snails and mosquitoes in the backwater.

5.1 Favourable vector habitats

- Borrow pits are common areas for vector production. Earth for the construction of dams, dikes canals or roads is frequently taken from the adjacent land, often leaving pools and marshes. 65
- Bridge piers: Flowing debris deposited at the upstream end of a pier (cut-water) as well as the oxygenized water at the downstream end (ease-water) may create vector habitats: the former for mosquitos and eventually snails, the latter for black flies. 66,67
- Siphons: vegetation growth in silted inlets and outlets as well as standing water in the siphon often produce snail and mosquito larval habitats.
- Roads, railway lines, small dams build up runoff water in the rainy season, creating puddles and marshes if no drainage and/or drainage culverts are provided. 68,69
- Tanks or lakes for irrigation purposes formed by putting up an earthen embankment along the lower run of a basin and which are fed by canal or natural catchment flow cause similar problems as the shoreline of impoundments.
- Cascade falls, and other drops built in a canal if the slope of the ground is sufficiently long and involves a steep decline are excellent habitats for *Simulium* larvae in endemic onchocerciasis areas. 70,71
- Maintenance of groundwater wells and hydrants often is lacking or poorly done causing puddles. This may result in intensive man/vector contact in which disease transmission in the area is increased.
- The advantages of pipes and closed conduits can only be sustained if they are properly maintained without leaking which produces puddles and small swamps. 72,73
- Often, due to inadequate planning, ancillary structures are installed, either finished or half-finished, but never put to use. They are left to decay and may often constitute breeding places for vectors.

5.2 Environmental management measures

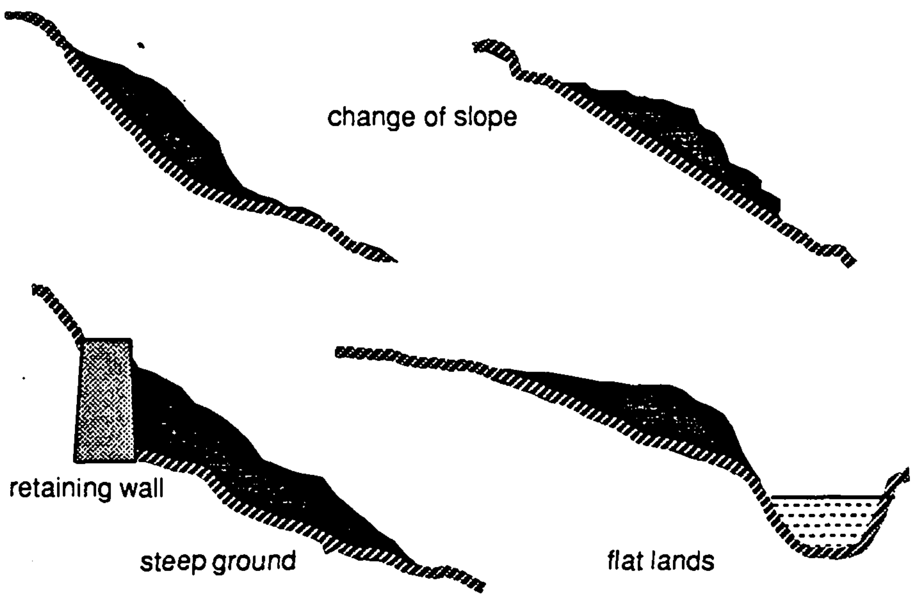
- Hydraulic shaping of regulation and operation systems to prevent silting up and/or erosion. Siphons should be supplied with scour valves to empty and dry up the siphon periodically. 74-76
- Flushing of regulation and operation systems.
- The covering of siphon inlets and outlets, as well as small tanks with wood or sheet-metal, suppresses weed and algae growth as well as the

development of vector sites.

- Proper maintenance here also acts as a safety measure in a fail safe function in control of disease transmitting vectors.
- Earth needed for filling or construction works should be taken from the ground without leaving borrow pits as illustrated in the following figure:

Figure 12: DIFFERENT SITUATIONS WHERE FILLING MATERIAL CAN BE OBTAINED WITHOUT RISK OF PRODUCING VECTOR HABITATS (Source: WHO Offset Publication 66)

77



Source: WHO Offset publ. No. 66

August 1987

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TRAINING AIDS FOR LECTURES ON

ENVIRONMENTAL MANAGEMENT FOR VECTOR CONTROL

APPENDIX 1: DIDACTIC MATERIAL

Water related diseases can be classified into 4 major categories, as follows:

1: ***Water-borne diseases:***
infections spread through contaminated drinking water

2: ***Water-washed diseases:***
diseases due to the lack of proper sanitation and hygiene

3: ***Water-based diseases:***
infections transmitted through an aquatic invertebrate organism

4: ***Water-related vector-borne diseases:***
diseases transmitted by insects that depend on water for their propagation

SOME WATER RELATED DISEASES AND THEIR IMPORTANCE

Overhead tranparency No. 2

Disease group	*Disease*	*Estimated infection rate (1´000/year)*	*Estimated morbidity (1´000/year)*	*Estimated mortality (1´000/year)*
WATER-BORNE DISEASES	Diarrhoeal Diseases	not available	1´000´000	5´000
	Typhoid Fever	1´000	500	25
WATER-WASHED DISEASES	Ascariasis (=roundworm infection)	800´000-1000´000	1´000	20
	Ancylostomiasis (=hookworm infection)	700´000-900´000	1´500	50-60
WATER-BASED DISEASES	Schistosomiasis (Bilharzia)	200´000	?	500-1´000
WATER-RELATED VECTOR-BORNE DISEASES	Malaria	240´000	100´000	not available
	Lymphatic filariasis	90´200	2´000-3´000	low
	Onchocerciasis	17´800	340	20-50
	Japanese encephalitis	not available	20-40	case fatality ratio between 10-30%

SOME REASONS FOR THE HIGH PREVELANCE OF WATER-RELATED DISEASES

- ☞ Insufficient water supplies and sanitation as well as solid wastes disposal services
- ☞ Inadequate housing and lack of hygienic conditions
- ☞ Lack of good health care
- ☞ Unproperly designed and managed water resource development schemes

Hydraulic engineering is an important component of environmental management in which relevant activities include *drainage, stream canalization, lining of streams and canals, land levelling and filling to eliminate depression areas, seepage control, piped or covered canals and drains, weed control, improved water management, diking and dewatering,* and ***strict discipline in the use of water.*** These measures promote community health and contribute to its economic development. As a rule, no single method used by itself is sufficient to prevent occurrence of any or all of the listed diseases. ***An integrated control approach is needed, if permanent results are to be achieved.***

Objective of environmental management for vector control:

reduction of the population density of target species below disease transmission threshold levels.

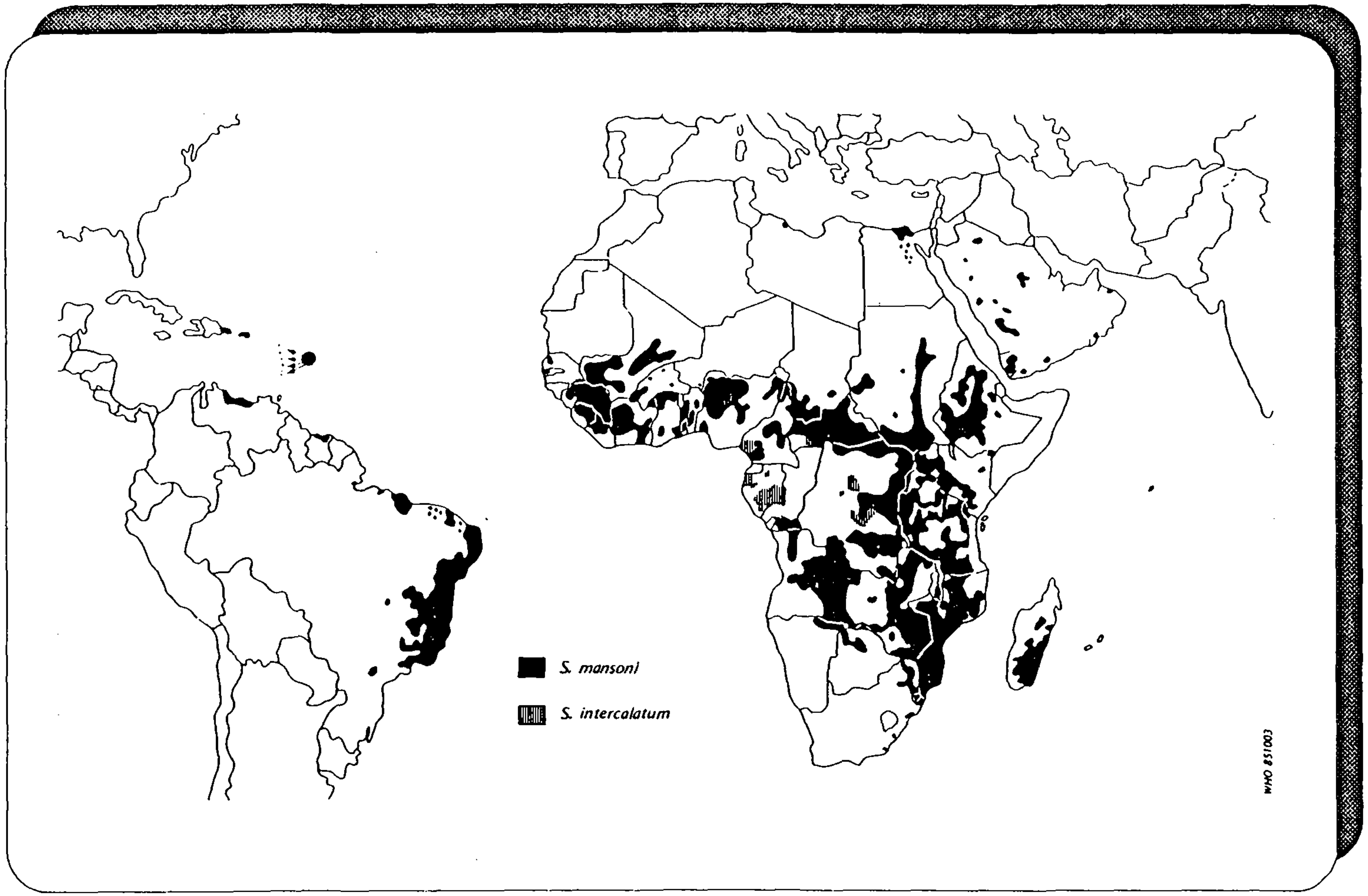
Relies on:

understanding of vector ecology and population dynamics
understanding of vector-borne disease epidemiology.

ASSOCIATION BETWEEN VECTORS/ HABITATS AND DISEASES

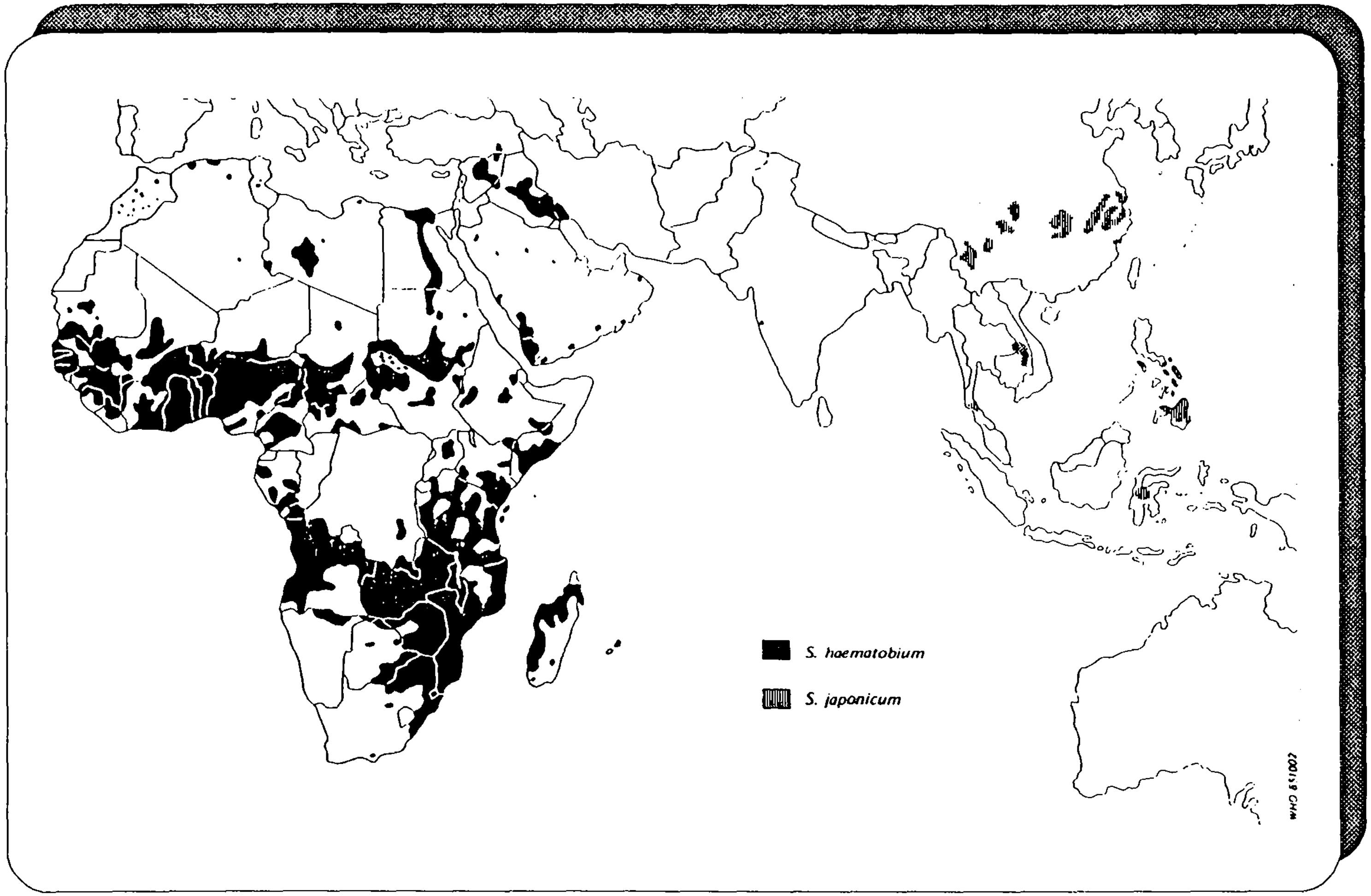
			Culicine mosquitoes	Anopheline mosquitoes	Simuliid blackflies	Oncomelania snails	Biomphalaria snails	Bulinus snails
DISEASE	**Arbovirus Diseases:**	Dengue	●					
		Yellow fever	●					
		Japanese encephalitis	●					
	Filariasis:	Bancroftian	●	●				
		Brugian	●					
		Onchocerciasis			●			
	Malaria:			●				
	Schisto-somiasis:	mansoni					●	
		haematobium						●
		japonicum				●		
RELATION TO WATER		immature stages live in water	●	●	●			
		lives near water	●	●	●	●		
		entire lifecycle in water	●			●	●	●
PREFFERED HABITAT		rain forests	●	●				
		riverian vegetation		●				
		irrigation ditches and canals	●	●		●	●	●
		lakes and ponds		●		●	●	●
		wetland rice cultivation		●		●	●	●
		rivers and streams		●	●	●	●	●
		human settlements	●	●			●	●
		coastel plains	●	●				

GEOGRAPHICAL DISTRIBUTION OF SCHISTOSOMIASIS MANSONI AND S. INTERCALATUM (source: WHO)



Overhead Transparency No.8

GEOGRAPHICAL DISTRIBUTION OF SCHISTOSOMIASIS HAEMATOBIUM AND S. JAPONICUM (source: WHO)



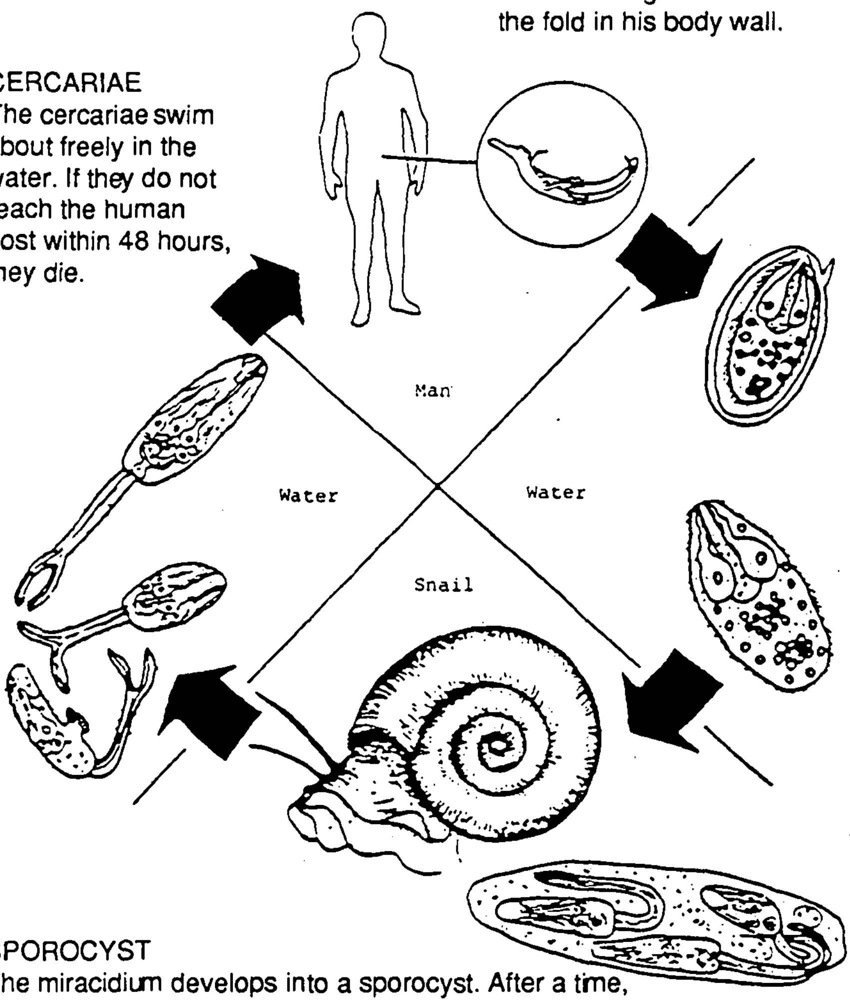
THE PRINCIPAL GENERA OF SNAILS AND THE PRINCIPAL FORM OF SCHISTOSOMIASIS WHICH THEY TRANSMIT

SNAIL GENUS	LIFECYCLE	PARASITE	TYPE OF DISEASE
Oncomelania	semi-aquatic	S. Japonicum	intestinal
Biomphalaria	aquatic	S. mansoni	intestinal
Bulinus	aquatic	S. haematobium	urinary

THE LIFECYCLE OF A SCHISTOSOME

ADULT WORMS
Adult worms live inside human veins. The inset illustration shows the fatter male worm holding the thinner female worm within the fold in his body wall.

CERCARIAE
The cercariae swim about freely in the water. If they do not reach the human host within 48 hours, they die.



EGGS
Eggs contain the larvae which are passed with the urine and faeces of an infected person

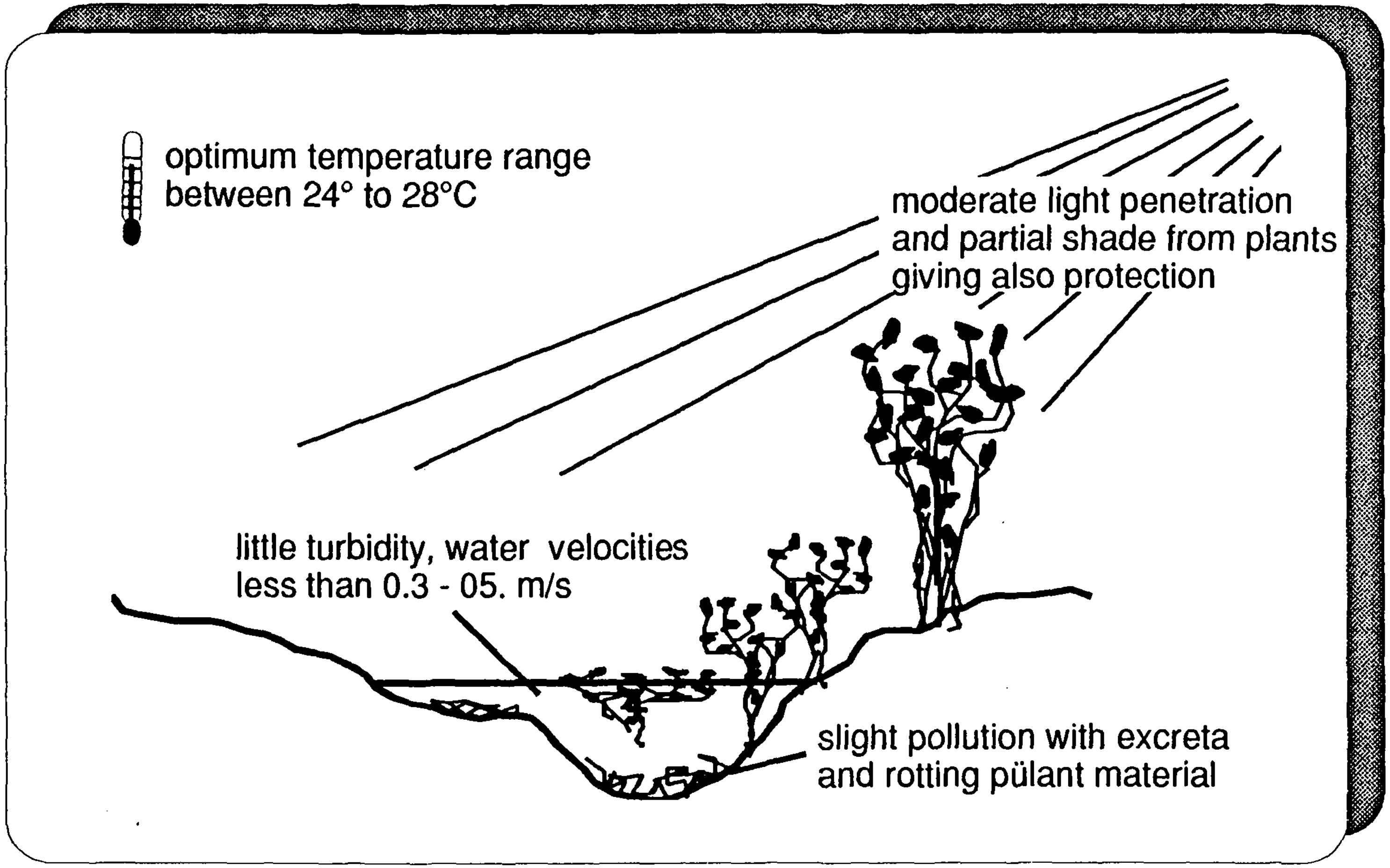
MIRACIDIUM
The miracidium larva hatches from the egg in water. After a free life of about six hours it seeks out and enters an aquatic snail

SPOROCYST
The miracidium develops into a sporocyst. After a time, fork-tailed larvae or cercariae are produced within the sporocysts, from which they ultimatly break out.

To interrupt the lifecycle of schistosoma parasites,

- ✍ *the man-water contact has to be minimized*
- ✍ *no faeces or urine should enter water*
- ✍ *the number of snails has to be diminished*

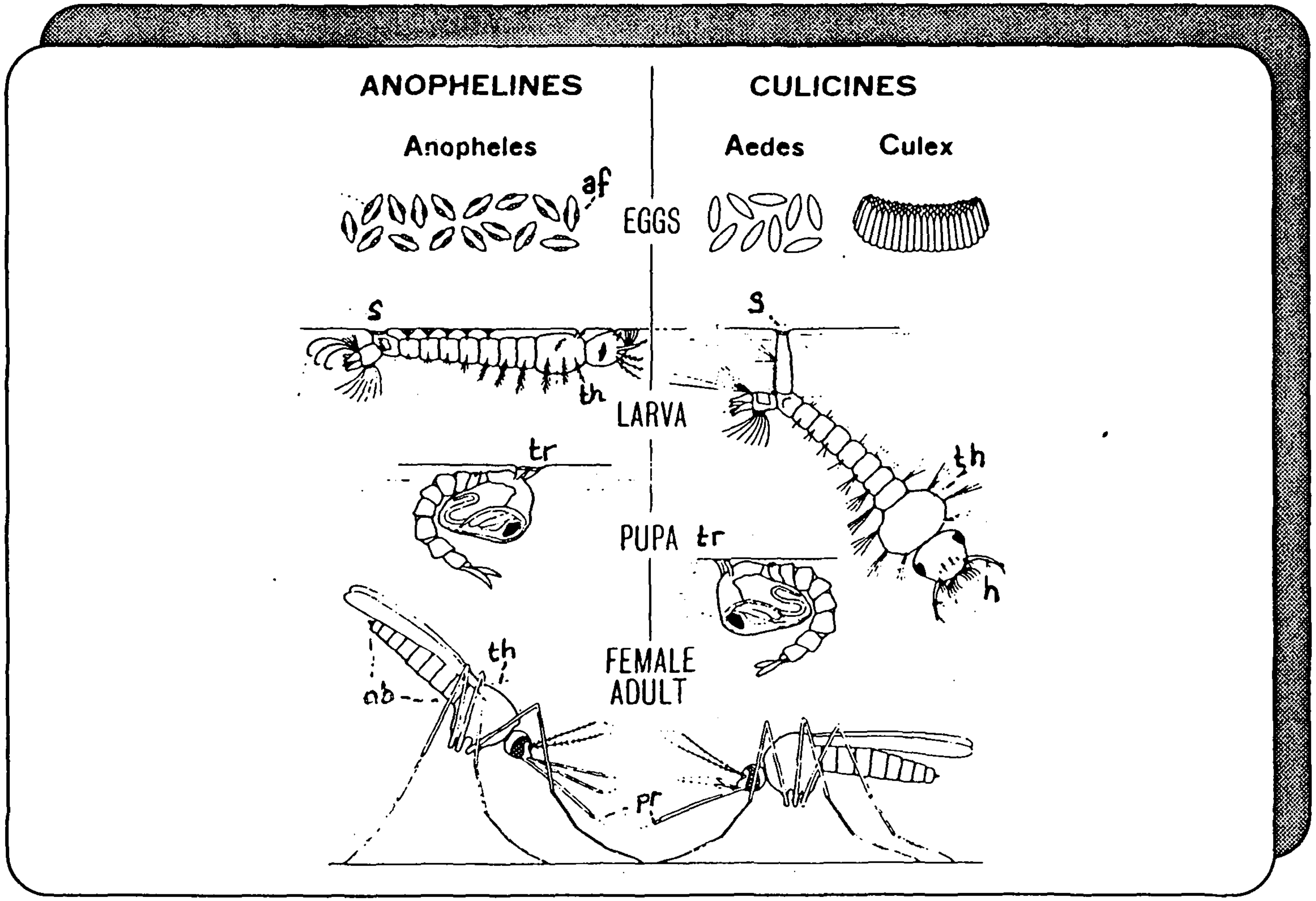
Overhead Transparency No.12



MAJOR MOSQUITO BORNE DISEASES

- MALARIA
- FILARIASIS
  - Wuchereria bancrofti
  - Brugia malayi
  - Brugia timori
- JAPANESE ENCEPHALITIS
- DENGUE FEVER
- YELLOW FEVER

CHIEF DISTINGUISHING FEATURES OF ANOPHELINES AND CULICINES

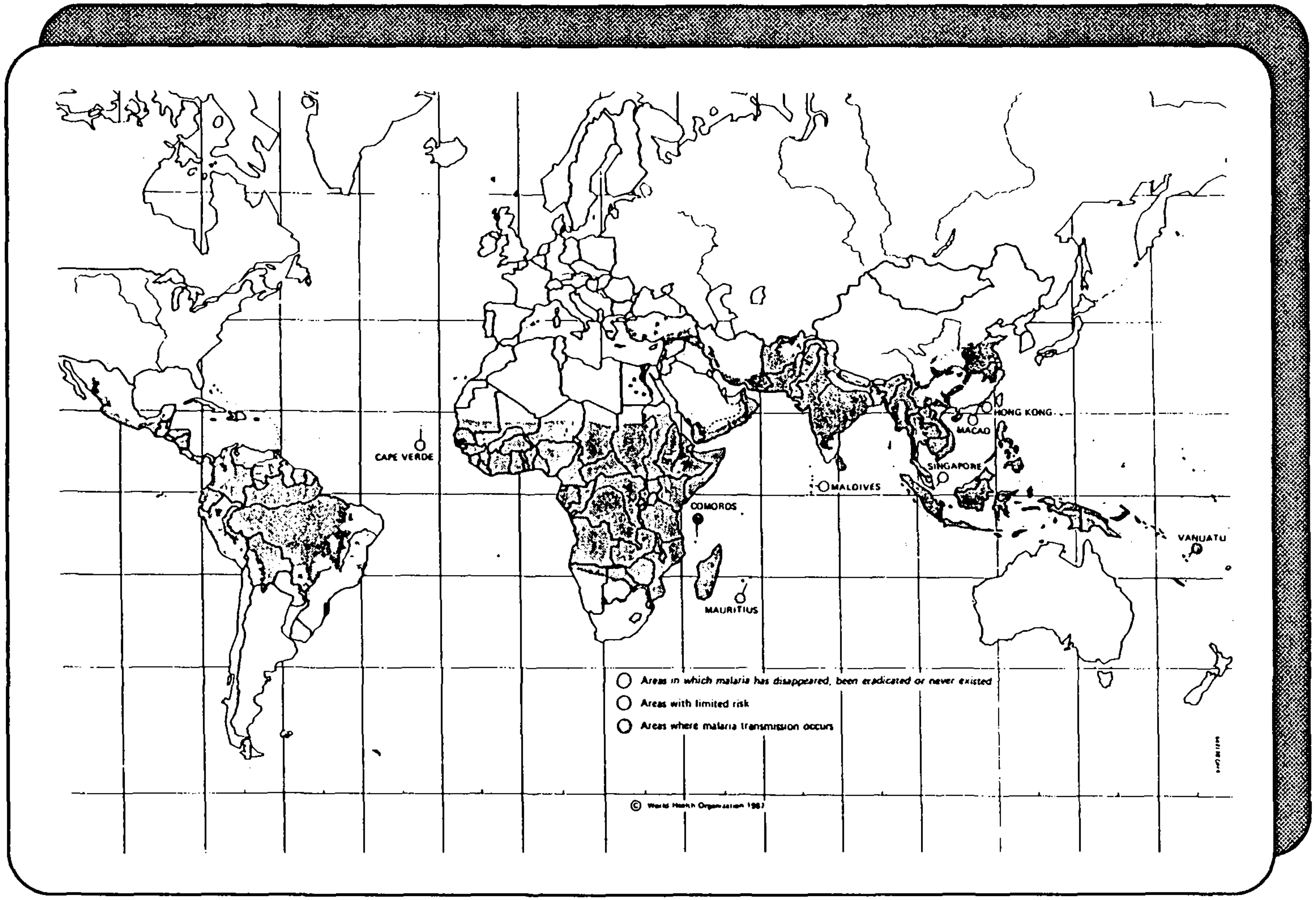


Water is an essential component of the mosquito environment. The water habitat, running or standing, clean or polluted, sweet or brackish, shaded or sunlit, permanent or intermittent, is a predominant factor determining which species of mosquito breed in it.

Mosquitoes as a group breed in an almost infinite variety of sizes and types of water bodies. Most disease transmitting species, however, breed only in a restricted narrow range of habitats, while only few species breed readily in a wide range of habitats.

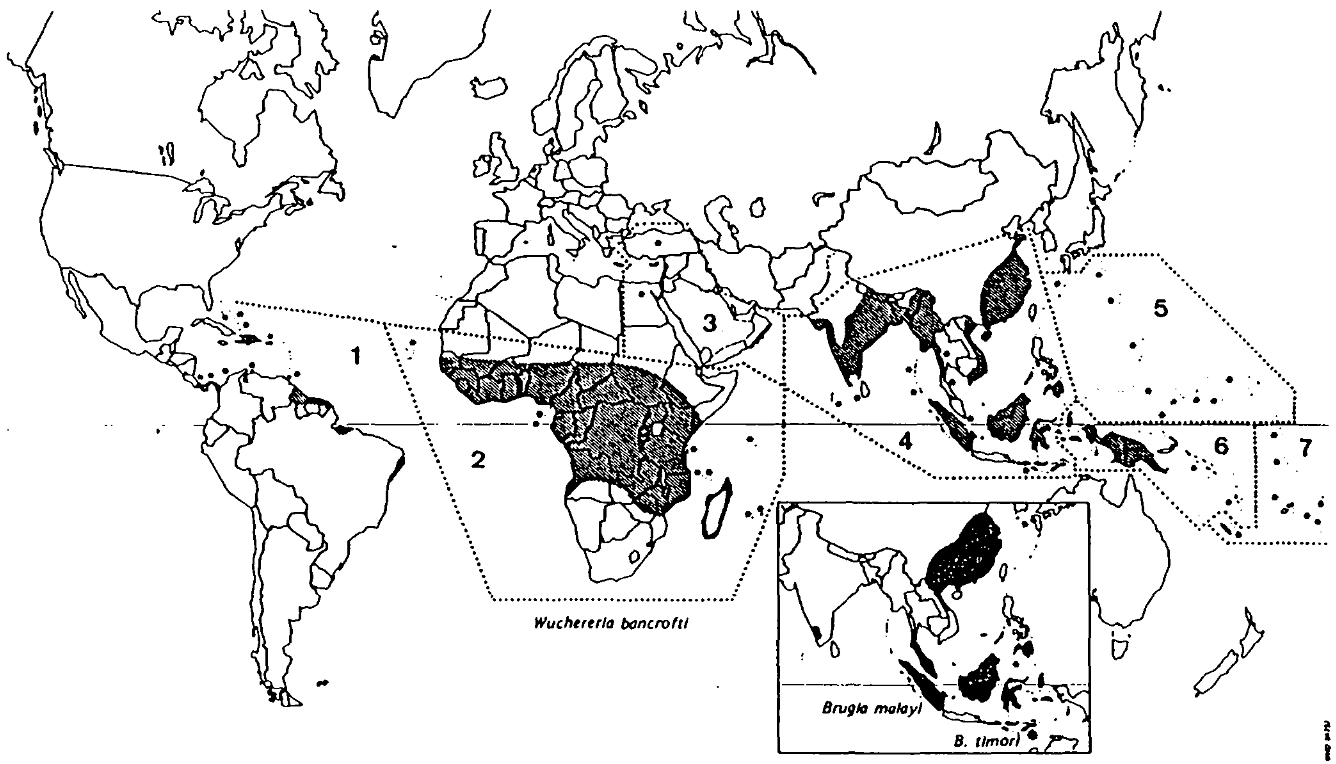
Overhead Transparency No.17

GEOGRAPHICAL DISTRIBUTION OF MALARIA



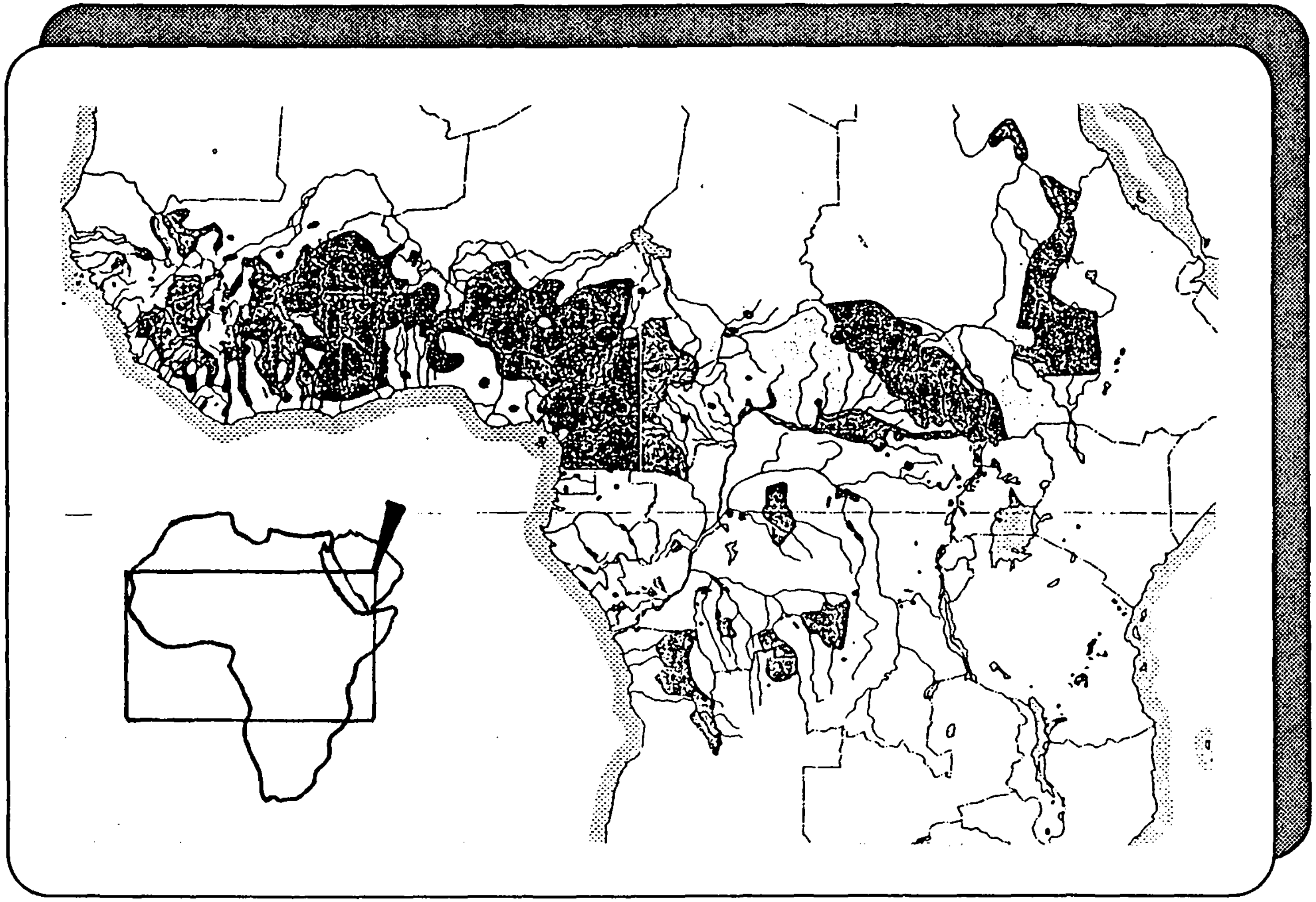
Overhead Transparency No.18

GEOGRAPHICAL DISTRIBUTION OF WUCHERERIA BANCROFTI, BRUGIA MALAYI AND B. TIMORI

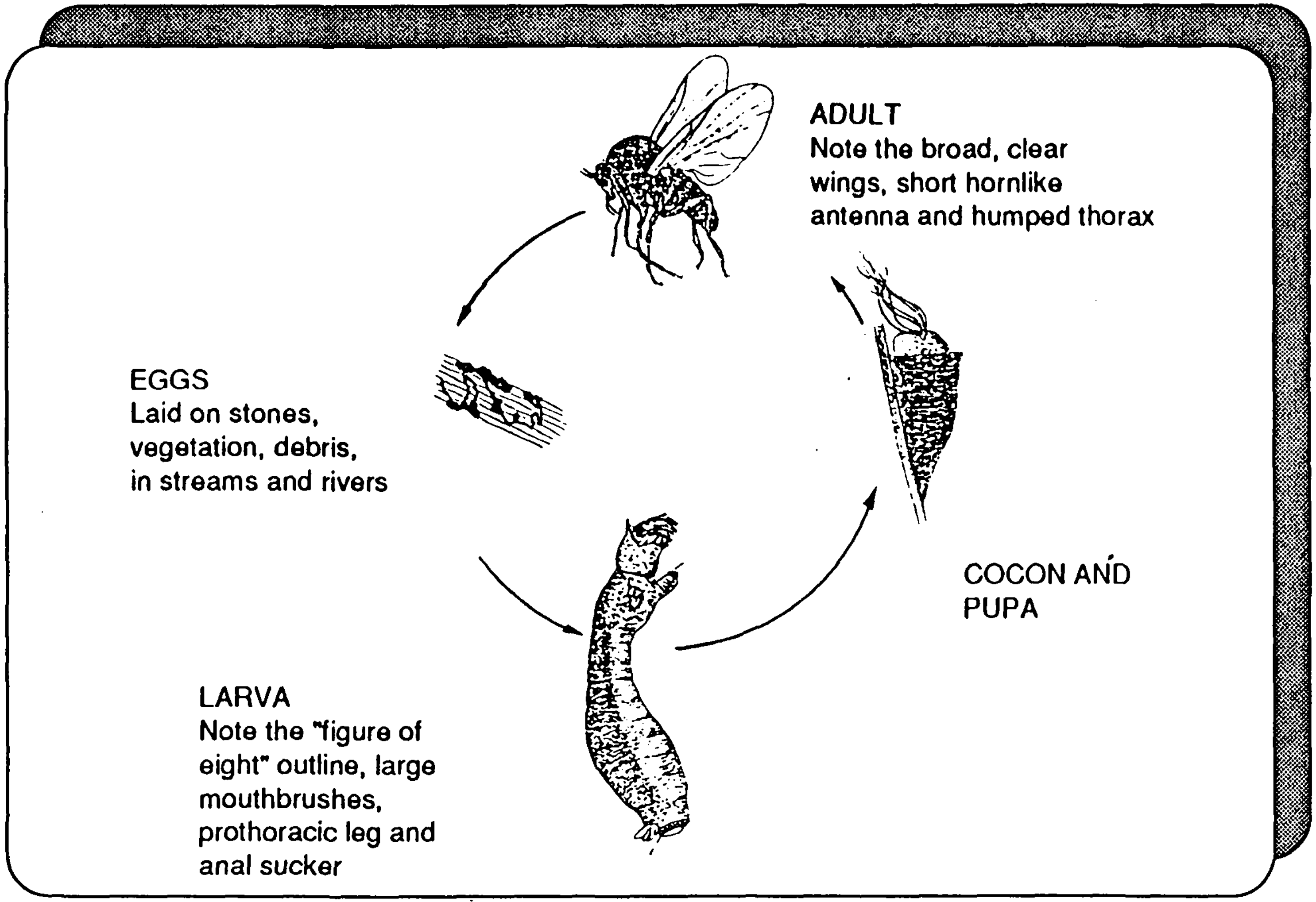


Overhead Transparency No.19

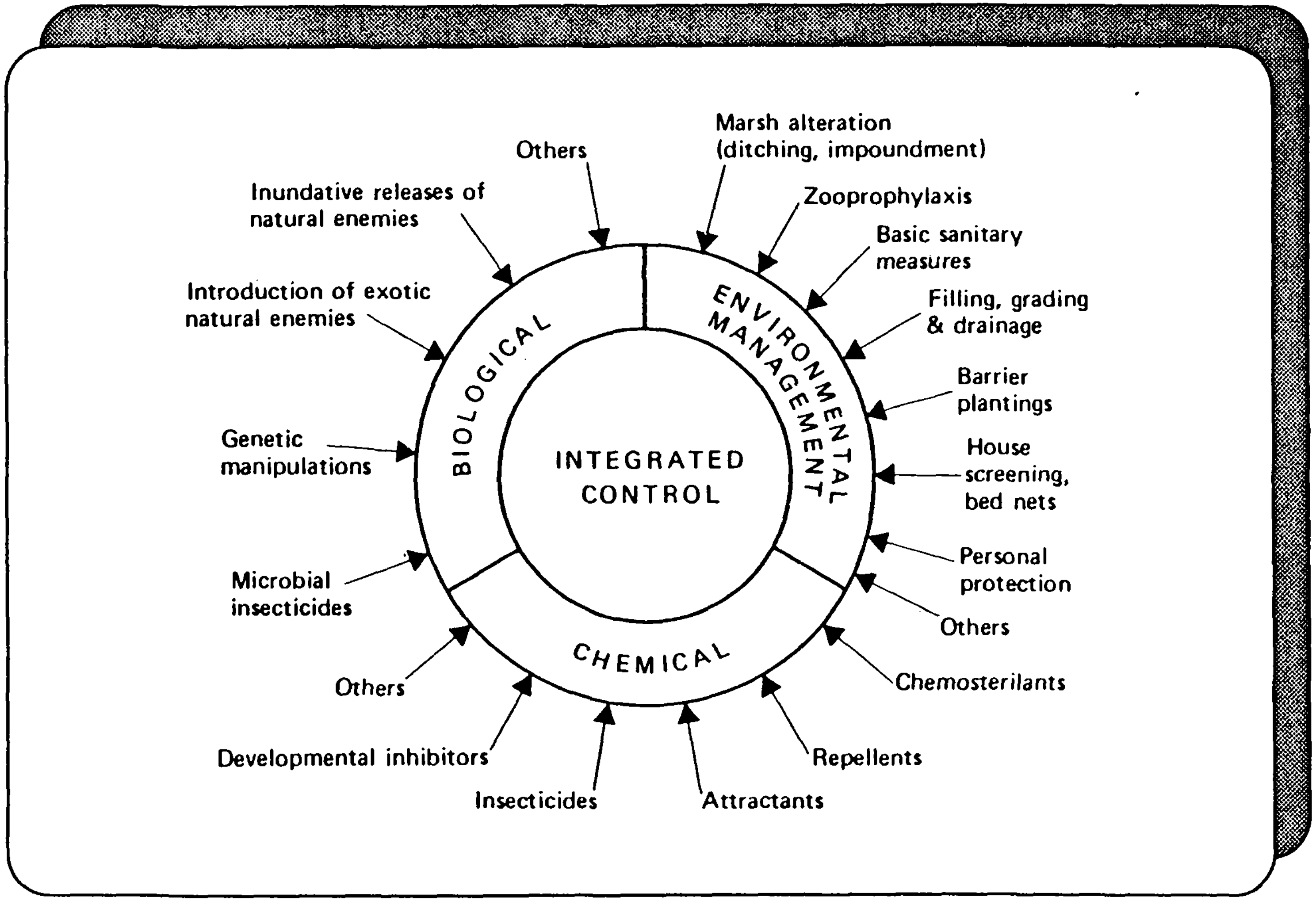
GEOGRAPHICAL DISTRIBUTION OF ONCHOCERCIASIS



THE LIFECYCLE OF SIMULIUM DAMNOSUM



CONCEPT OF INTEGRATED VECTOR CONTROL



Environmental management for vector control: **The planning, organization, carrying out and monitoring of activities for the modification and/or manipulation of environmental factors or their interaction with man with a view to preventing or minimizing vector propagation and reducing man-vector-pathogen contact.**

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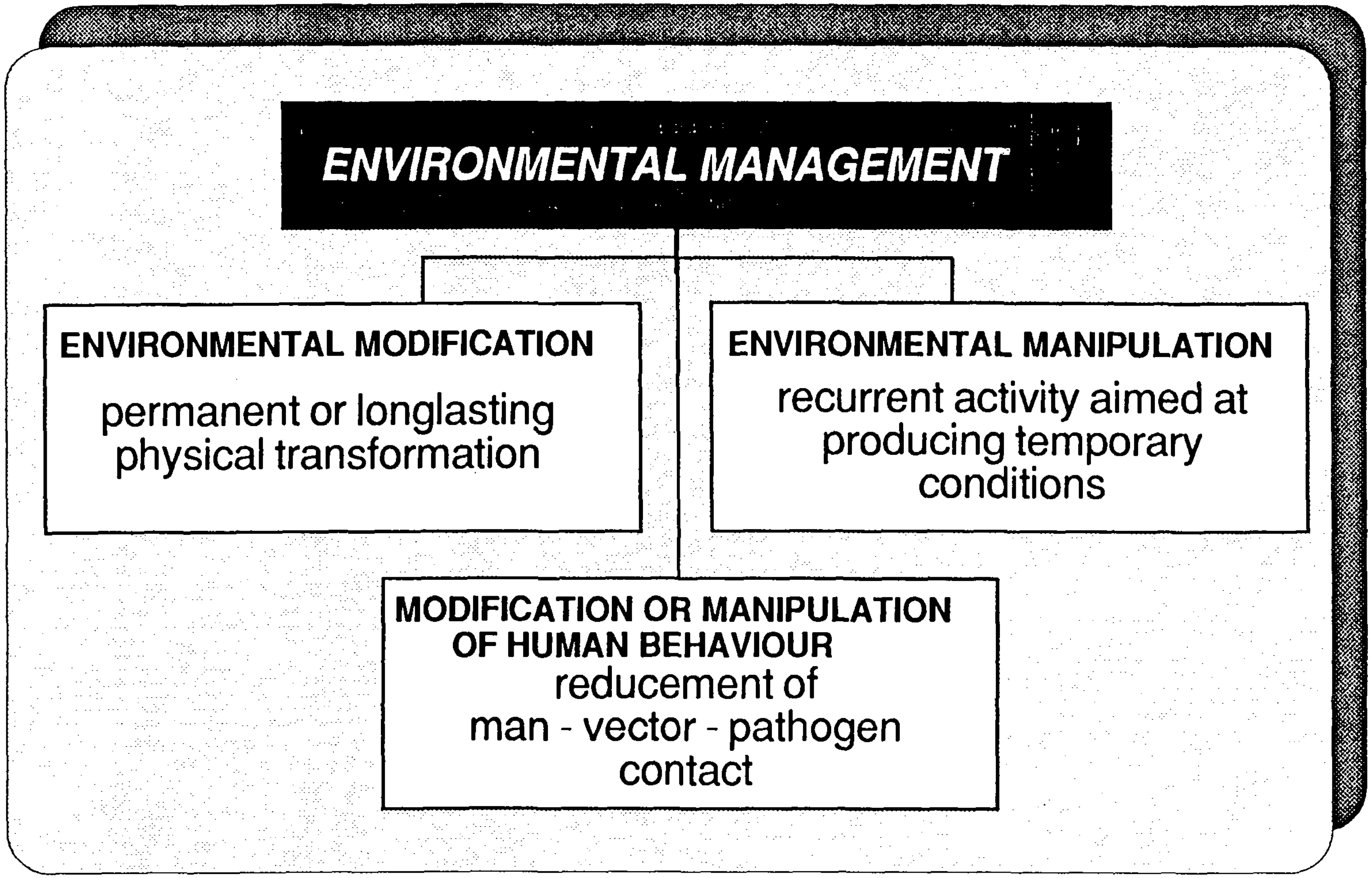

ENVIRONMENTAL REQUIREMENTS

- Many vectors require an *aquatic environment,* either in the immature stage (mosquitoes, black flies) or in the immature stages (snails).
- *Aquatic weeds,* if not to dense, promote vector development, giving them *protection* from direct sunlight, natural enemies, wind and water current (except black flies) as well as providing *fodder* (snails).

BASIC QUESTIONNAIRE FOR ENVIRON-MENTAL MANAGEMENT MEASURES

- ☞ are additional water bodies essential and which are the important water properties (quality, flow velocities)?
- ☞ How is the micro-climate affected (i.e., raising of humidity and average warm temperature favours vector breeding.)?
- ☞ Which aquatic weeds are involved (in addition to protection, many vectors are associated with specfic weeds.)?
- ☞ What are the consequences on the behaviour of the inhabitants (settlements near impoundments and irrigation channels.)?

TRAINING AIDS FOR LECTURES ON ENVIRONMENTAL MANAGEMENT FOR VECTOR CONTROL

APPENDIX 2 – 5
Additional reading list
Glossary
Basic informations on mosquito vectors and diseases
Slide captions

ADDITIONAL READING LIST

WHO, Offset Publication No. 66
Manual on Environmental Management for Mosquito Control
Geneva, 1982

FAO irrigation and drainage paper No. 41
Environmental Management for Vector Control in Rice Fields
Rome, 1984

WHO/FAO/UNEP
Guidelines for Forecasting the Vector-Disease Implications
in the Development of Water Resource Projects
Geneva, 1987, preliminary draft version

Operation & Maintenance of Irrigation and Drainage Systems
ASCE Publication No. 3, Manual on Engineering practice No. 57
American Society of Civil Engineers

Abraham S. Benenson:
Control of Communicable Diseases in Man
American Public Health Association

A.D. Berrie:
Snail Problems in African Schistosomiasis
1970; Academic Press, London & New York

C.Th. Cheng:
Molluscicides in Schistosomiasis Control
1974; Academic Press, London & New York

R.G. Feachem, D.J. Bradley, H. Garelick, D.D. Mara:
Health Aspects of Excreta and Sullage Management
Reihe: Appropriate Technology for Water Supply and Sanitation
World Bank/December 1980

J.B. Kalbermatten, DA.S. Julius, Ch.G. Gunnerson:
A Sanitation Field Manual
Reihe: Appropriate Technology for Water Supply and Sanitation
World Bank/December 1980

Emile A. Malek
Snail transmitted Parsitic Diseases
Volume 1
1980; CRC Press, London & New York

R.C. Muirhead-Thompson:
Exology of Insect Vector populations
1968; Academic Press, London & New York

K.R. Snow
Insect and Disease
1974: Ronfledge & Kegan Paul, London

N.F. Stanley, M.P. Alpers:
Man-made Lakes and Human Health
1975; Academic Press, London, New York, San Francisco

J.J. McKelley, B.F. Eldridge, K. Maramonosch
1981: Praeger Publishers, New York

Water and Man's Health
USAID, Wahington DC, 1962
Reprint 1967

Water, Engineers, Development and Disease in the Tropics
USAID, Wahington DC, 1975

E. Barton Worthington:
Arid Land Irrigation in Developing Countries;
Environmental Problems and Effects
Pergamon Press

WHO Technical Report Series:

Nr. 265,	1963:	Vector Control
Nr. 356,	1967:	Safe Use of Pesticides in Public Health
Nr. 404,	1968:	Water Pollution Control in Developing Countries
Nr. 501,	1972:	Vector Ecology
Nr. 603,	1977:	Engineering Aspects of Vector Control Operations
Nr. 639,	1979:	Human Viruses in Water, Wastewater and Soils
Nr. 640,	1979:	WHO Expert Commitee on Malaria
Nr. 643,	1980:	Epidemiology and Control of Schistosomiasis
Nr. 649,	1980:	Environmental Management for Vector Control
Nr. 655,	1980:	Resistance of Vectors of Disease to Pesticides
Nr. 679,	1982:	Biological Control of Vectors of Disease
Nr. 680,	1982:	Malaria Control and National Health Goals

GLOSSARY

HEALTH

AEDES	A genus of Mosquitoes, including some 600 species, many of which are vectors of disease.
ANOPHELINES	Any of the various mosquitoes constituting the genus Anopheles, some species of which transmit the malaria parasite to man.
BIOMPHALARIA	Aquatic freshwater snail species of the family Planorbidae, sub-family Planorbinae; intermediate host of Schistosoma mansoni.
BULINIDS	Aquatic frshwater snails of the family Planorbidae, sub-family Bulininae: major intermediate host of Schistosoma haematobium.
CERCARIAE	Larval forms of trematode worms, with short forked tails and resembling an immature adult.
CULEX	A genus of mosquitoes found throughout the world, many species of which are vectors of disease-producing organisms.
CULICINE	A mosquito of the genus Culex or related genera.
ECOLOGY	The study of an organism's relationship to its environment.
ENDEMIC	Any disease of man, maintained at a fairly constant low level in the community over a period of years.
ENDOPHILIC	Insects with a preferred resting place indoors.
ENDOGENOUS	Produced from within; originating from or due to internal causes.
ENVIRONMENT	The physical and biological characteristics of a certain area.
EPIDEMIC	Any disease of man in which the number of cases exceeds that normally expected.
EXOGENOUS	Developing or originating outside an organism or part of an organism; or relating to an external factor, such as light, that influence an organism.
FILARIAL	Any parasitic nematode worm of the family Filaridae, living in the blood and tissues of vertebrates and transmitted by insects; the cause of filariasis.
HABITAT	The physical place (home) where an organism lives.
HELMINTHIC	Related to worms, especially a nemathode or fluke.
HOST	A man or animal which harbours a disease-producing organism.
MIRACIDIA	Flat ciliated larvae of flukes that hatch from the egg and give rise asexually to other larval forms.
MORBIDITY	Number of disease cases.
MORTALITY	Number of deaths.
NEMATODE	A class of cylindrical or slender thread-like worms, chiefly parasitic in animals and plants.
ONCOMELANIA	A genus of amphibious snails, serving as intermediate host of Schistosoma japonicum.
PARASITE	A plant of animal living in, on, or with another living organism at whose expense it obtains its food and shelter.
PATHOGEN	An organism or virus capable of causing disease.
pH	A measure of acidity or alkalinity of a material, liquid or solid. pH is represented on a scale of 0 to 14, with 7 representing a neutral state, 0 representing the most acid, and 14 the most alkaline. pH is the logarithm of the reciprocal of the hydrogenion concentration or $pH = \log 1/H^+$.
PLANORBIDS	Aquatic freshwater snails of the sub-family Planorbinae.
POPULATION DENSITY	The number of individuals of a given species within a given geographical area.
PREVALENCE	Ratio of number of persons sick with the specified disease at a particular moment in time related to the total population in question.

PRIMARY VECTOR	The main vector species that transmit a pathogen to man or other animals.
PROTOZOAN	Any minute invertebrate of the phylum Protozoa, including flagellates, ciliates, sporozoans, amoebas and foraminifers.
SPECIES	A taxonomic division of a genus. Members are similar and the sexes can mate and produce fertile offspring.
SPOROCYST	A cyst or capsule containing spores, forming a stage in the development of trematodes, etc.
STAGE	A definite period in the growth of an insect i.e., egg, larvae, adult.
TREMATODE	Any parasitic flatworm of the class Trematoda, which includes the flukes.
VECTOR	An organism that transmits or transports a pathogen such as viruses, bacteria, or protozoans from one organism to another.
ZOOPROPHYLAXIS	The use of wild or domestic animals, which are not the reservoir hosts of a given disease, to divert blood-seeking insect vectors from the human hosts of that disease.

ENGINEERING

APRON	A protective layer of stone or other material extending out from a structure or situated in some other location where it is desired to prevent erosion.
CANAL FLUSHING	Removal of deposited sediment and breeding vectors by means of a rush of water.
CANAL LINING	A protective covering over the entire, or a portion, of the perimeter of a conduit to prevent seepage losses, to withstand pressure, to resist erosion and to control weeds and vectors. Linings are sometimes provided to reduce friction or otherwise improve conditions of flow.
CONDUIT	A device for conveying water under an embankment, under pressure or at atmospheric pressure.
CULVERT	A transverse drain or waterway structure under a road, railroad, canal, or through an embankment by means of a pipe or enclosed channel.
DRAINAGE	The disposal of water from rural areas, and the removal of water excess from agricultural lands to prevent or to relieve waterlogging, the accumulation of harmfull amounts of salts, the deterioration of soil structures and the control of vectors.
INTERMITTENT IRRIGATION	With the exception of the period of seedling planting, the water is supplied according to the needs of plants.
LAND LEVELLING	The moving of soil in preparing land for irrigation to produce a level or uniformly sloping surface.
MICRO/MACRO CLIMATE	Detailled climate of very small area of the earths surface, for example, a single forest or crop field. Contrast "macroclimate" which is the climate over a very large area, such as desert or ocean.
REGULATION STRUCTURES	Structures built in canals to provide specific control and measurement of water during conveyance to a location of usage or disposal.
SIPHON	A structure with a closed conduit, designed to run full and usually under pressure, to transport water under railroads, roads, canals and depressions.
SPILLWAY	1) A passage for spilling surplus water; a wasteway. 2) A surplusing work over the dam or upstream of the dam in the side ridge, in the form of open or closed conduit.
WATER RESOURCE DEVELOPMENT PROJECT	Activity directed to developing or utilizing water resources for beneficial use

BASIC INFORMATIONS ON MOSQUITO VECTORS AND DISEASES

Extract from WHO Offset Publication No. 66: MANUAL ON ENVIRONMENTAL MANAGEMENT FOR MOSQUITO CONTROL; WHO Geneva, 1982

A. Important malaria vectors

The basic epidemiology of malaria involves a man-*Anopheles*-man transmission cycle. Usually transmission takes place indoors, the dangerous vector entering the houses at night to feed on man; it may also occur outdoors where people sleep or spend the evening hours outside their houses. Malaria epidemiology depends on environmental factors (climate, topography, hydrology, housing), on human factors (land use and occupation, daily activities and habits, migration of people, malaria prevalence), and on entomological factors (density, flight range, breeding, feeding and resting habits of mosquitos, and infection rate).

All mosquito larvae require water for their development and almost all sorts of water locations have been exploited by the several thousands of mosquito species. In the choice of breeding places, certain species are highly selective; other species are rather indifferent and their larvae may be found in a wide variety of water bodies. Despite many years of research there is still no clear understanding of the natural propensity of the female mosquito to select a particular type of water as being most suitable for oviposition.

Major factors that determine habitat preference are shade or sun exposure, quiet or flowing water, temperature, salt content, surface vegetation and floatage, and organic pollution. The following classification attempts to identify the most common breeding habitats and to indicate for each type the most suitable environmental management measures for its control.

A. Large bodies of fresh water in full or partial sunlight. Larvae occur in floating or emergent vegetation or floatage near the edges.

1. Impoundments, lakes, pools, bays, large borrow pits, slow rivers, and pools in drying beds of rivers and major streams.
2. Marshes, bogs, and swamps.

Control: Shoreline straightening by cutting, deepening and filling; shoreline preparation by levelling, grading and clearing vegetation; filling or draining side pockets; water level management; introduction of natural enemies and predators; drainage, filling, and ponding or canalizing of marshes and swamps.

B. Small collections of seepage water, stagnant and often muddy, but not polluted; full to partial sunlight. Vegetation present or absent.

1. Semipermanent rain pools or overflow water; roadside ditches, clogged drainage ditches, small borrow pits, wheel ruts, hoofprints, natural depressions on the ground, and puddles at the edge of ricefields.
2. Desert saline pools.

Control: Filling and grading; drainage.

C. Ricefields.

Control: Intermittent irrigation of paddy fields with flooding and drying periods; grading of paddies and ditches for rapid dewatering; vegetation clearance.

D. Brackish or saltwater marshes and lagoons; saltwater fish ponds; full or partial sunlight.

Control: Drainage, deepening and filling, ponding, canalizing, changing salinity by using tidegates and dikes, marshland reclamation, and vegetation clearance.

E. Partially or heavily shaded water in forests or jungles.

1. Pools, ponds, swamps, and sluggish streams.
2. Springs, shallow seepages and puddles on forest ground.

Control: Drainage, filling, ponding, canalizing, vegetation removal, and jungle clearance.

F. Running water courses, clear fresh water, direct sunlight.

1. Shallow gravelly stream beds with emergent grass and weeds.
2. Margins of foothill streams; small irrigation channels of upland ricefields.
3. Lowland grassy or weedy streams and irrigation ditches.
4. Stream bed pools and side pockets with abundant algae mats.
5. Pools in drying stream beds.
6. Rock holes in stream beds.

Control: Stream bed correction and clearance, channelling, ponding, sluicing and flushing, shading, and vegetation and debris clearance.

G. Springs; seepages from streams, irrigation channels and tanks; clear water; direct sunlight.

Control: Drainage, filling, repair of leaks in dams and embankments, and vegetation clearance.

H. Plant hollows and cavities: epiphytic arboreal and terrestrial bromeliads.

Control: Destruction of water-holding plants.

I. Man-made containers: wells, cisterns, water storage tanks, ornamental basins, tins, plastic packages, etc.

Control: Tight covers or screens for essential water storage cisterns, barrels, etc., and emptying, piercing or destroying unnecessary water containers.

Table 1.1 presents a list of the Anopheles mosquitos most commonly incriminated in malaria transmission and their chief preferences in breeding habitats; they are grouped according to geographical distribution. The symbols used for habitats agree with the above classification. A capital letter denotes a definite preference for such type of habitat; a small letter indicates that, to a lesser degree, larvae of the particular species are found in this type of habitat, either in the presence or absence of the preferred habitat.

Important malaria vectors

Region	Anopheles species	Habitat**
1. North America		
(a) Southeastern	quadrimaculatus Say	A1,2; b1
(b) Southwestern	freeborni Aitken	C; F3; G
(c) Mexico	albimanus Wiedemann	A1,2; B1; G
	pseudopunctipennis Theobald	F4
	aztecus Hoffman	A1; E
2. Central America and West Indies	*albimanus Wiedemann	A1,2; B1; d
	aquasalis Curry	D
	pseudopunctipennis	F4; g
	bellator Dyar and Knab	H
	punctimacula Dyar and Knab	E1
3. South America	*darlingi Root	E1; a1,2
	*albimanus Wiedemann (Ecuador), Colombia, Venezuela)	A1,2; B1; d
	aquasalis Curry	D
	pseudopunctipennis Theobald (Northern and Western)	F4; g
	*nuneztovari Gabaldon (Northern)	A2
	albitarsis Lynch Arribalzaga	A1,2
	punctimacula Dyar and Knab	E1
	bellator Dyar and Knab	H
	cruzii Dyar and Knab	H
4. North European and Asiatic regions	labranchiae atroparvus Van Thiel	D
	maculipennis messeae Falleroni	A1,2
	*sacharovi Favre	D; a2
	sinensis Wiedemann (Southern China)	C; A1
	pattoni Christophers (Northern China)	F4,5

* Species responsible for continuing transmission.

5. Mediterranean region	*sacharovi Favre	D; a2
	labranchiae labranchiae Falleroni	D; c
	l. atroparvus Van Thiel (Spain, Portugal)	D; c
	*superpictus Grassi	F1; f3; G
	claviger Meigen	B1; F5
	m. messeae Falleroni	A1,2
	sergentii Theobald	C; F3; b1; g
	hispaniola Theobald	A2; F4
6. Desert (North Africa and Arabia)	*sergentii Theobald	C; F3; b1; g
	*pharoensis Theobald	A2; c
	multicolor Cambouliu	B1,2; i
	hispaniola Theobald	A2; F4
7. Ethiopian region		
(a) Africa	dthali Patton	F3; g; i
	pharoensis Theobald	A2; c
	*gambiae Giles arabiensis Patton	B1
	*melas Theobald (West coast)	D
	merus Dönitz (East coast)	D
	*funestus Giles	A1,2
	nili Theobald	F3
	moucheti Evans	A2
(b) Yemen	*gambiae s.l.	B1
	culicifacies Giles	F4,5; B1; C; I
	sergentii Theobald	C; F3; b1; g
8. Middle East and South-East Asia	*culicifacies Giles	F4,5; B1; C; I
	*stephensi Liston	I; b1; f3,5
	minimus Theobald	F2
	*fluviatilis James	F2; a2
	varuna Iyengar	F2
	annularis van der Wulp	A1
	philippinensis Ludlow	A1,2; C
	*hyrcanus Pallas	C
	*pulcherrimus Theobald	C
	*superpictus Grassi	F1; G; f3
	sundaicus Rodenwaldt	D
	dthali Patton	F3; g; i
9. Hill zones of Burma, Thailand and Indo-china	*minimus Theobald	F2
	*balabacensis balabacensis Baisas	E2
	annularis van der Wulp	A1
	maculatus Theobald	F2; g

10.	South-East Asia region (Malaysia, Indonesia, Philippines, coastal plains from south China to Bengal)	sundaicus Rodenwaldt	D
		letifer Sandosham	E1
		umbrosus Theobald	E1
		*b. balabacensis Baisas	E2
		maculatus Theobald	F2; g
		minimus Theobald	F2
		minimus flavirostris Ludlow (Philippines)	F2
		subpictus Grassi	B1; C
		sinensis Wiedemann	A1,2; c
		aconitus Dönitz	A1,2; C
		campestris Reid	A2; c; f3
		donaldi Reid	A2; C
		philippinensis Ludlow	A1,2; C
		leucosphyrus Dönitz	E1,2
11.	Chinese region (Central China, Korean peninsula, Japan)	sinensis Wiedemann	A1,2; C
		pattoni Christophers	F5,6
		lesteri Baisas and Hu	C
		martinius Shingarev	D; a2
12.	Southern & Western Pacific regions	*farauti Laveran	B1
		*koliensis Owen	B1; d
		*punctulatus Dönitz	B1
		bancrofti Giles	F3
		subpictus Grassi	B1
		karwari James	B1; F3; a1; g

B. Important vectors of lymphatic filariasis

In general, the basic epidemiology of filariasis involves a man-vector-man transmission cycle. However, the transmission of Brugia malayi filariasis (subperiodic form) may involve animal hosts or reservoirs such as domestic and wild cats, civets and pangolins; infection is transmitted from animal to animal or man, and from man to man or animal by certain species of Mansonia mosquitos.

A wide range of mosquitos, including several species of Anopheles of malaria importance, are vectors of the various forms of filariasis. This gives a universal character to the disease transmission; it can occur at any time of the day or night, indoors and outdoors, near or away from human centres. Larval habitats are also most diverse; depending on the species involved, breeding takes place in salt, brackish and fresh water, either clear or polluted, in large water bodies, tidal lagoons, marshes, ponds, or in water contained in leaf axils, tree holes, coconut husks, barrels, tins, etc.

In regions where different vector species are responsible for filariasis transmission, such as the Malaysian and Australasian regions, vector control becomes an extensive and expensive operation.

Table 1.3 presents a list of filarial parasites, their distribution in geographical regions and preferred types of environment, summary notes on the disease epidemiology and the mosquito species most commonly involved in the transmission.

Table 1.4 presents a list of the important mosquito vectors of filariasis in alphabetical order, with summary information on adult habits and larval habitats.

Table 1.3. Filarial parasites transmitted by mosquitos

Parasite and distribution	Epidemiology	Important vectors
Wuchereria bancrofti periodic form, throughout the tropics (except Polynesia), some subtropical areas.	Man-mosquito-man transmission cycle. Principal vectors enter houses at night to feed on man. In rural areas these are Anopheles species; in the forests and plantations of S.E. Asia, forest-dwelling species of Aedes (Finlaya) may be of local importance; in urban areas the chief vector is Culex quinquefasciatus Say.	Anopheles gambiae An. funestus An. darlingi An. minimus flavirostris An. campestris An. punctulatus group Aedes (F.) niveus Ae. (F.) kochi Ae. (F.) poecilius Culex quinquefasciatus Say (= Cx pipiens fatigans Wiedemann)
W. bancrofti diurnally subperiodic form, in Polynesia and New Caledonia; nocturnally subperiodic form, in Thailand.	Associated especially with coconut plantations, where the principal vector, Ae. polynesiensis, feeds by day on people working in these plantations or living in nearby houses. Locally, other species may transmit away from coconut plantations (see notes on vector biology, Table 1.6).	Ae. (S.) polynesiensis Ae. (S.) tongae Ae. (S.) pseudoscutellari. Ae. (F.) fijiensis Ae. (O.) vigilax

Brugia malayi nocturnally subperiodic form, swamp forests of Malaysia and the Philippines (Palawan, Sulu, Mindanao).	In addition to man, macaques and leaf monkeys, domestic and wild cats, civet cats and pangolins are subject to infection. Transmission from man to man, or animal to man, or man to animal, by swamp forest-dwelling species of Mansonia. Thus transmission takes place mostly in the swamp forest or in nearby villages by mosquitos which bite by day or night, indoors or outdoors, with the peak of activity during the evening.	Mansonia dives Ma. bonneae Ma. annulata Ma. uniformis
Brugia malayi nocturnally periodic form, in Japan, coastal China, Korean peninsula, South-East Asia, India; nocturnally subperiodic form, in western Malaysia.	Man apparently is the only natural vertebrate host, and transmission takes place primarily in the domestic environment by night-biting mosquitos, either indoors or outdoors. Endemic foci of S. Asia usually associated with flat, swampy land. In Japan, togoi-transmitted foci are in communities near coastal salt-water rock pools and cisterns.	Ma. annulifera Ma. indiana Ma. uniformis Ae. (F.) togoi An. campestris An. donaldi
Brugia timori nocturnally periodic, in Indonesia.	Vertebrates such as monkeys, domestic and wild cats, civets and pangolins are included in the developmental cycle, as well as man.	An. barbirostris

Notes on the biology of important filarial vectors

Species and distribution	Adult habits	Larval habitats
Aedes (F.) fijiensis Fiji Islands	Found naturally infected in Fiji. Persistent night-time biter.	Leaf axils of Pandanus and of some other plants
Ae. (F.) kochi Australian region	Bites man by day and night, indoors and outdoors; especially abundant in and near Pandanus groves.	Leaf axils of Pandanus, Colocasia, banana

Ae. (F.) niveus Philippines, Malaysia, Indonesia	Probable vector in forests.	Tree holes, bamboo stumps
Ae. (F.) poecilius Malaysia, Indonesia	Bites by day or night, indoors and outdoors; especially abundant in or near extensive abaca plantations in the Philippines.	Leaf axils of abaca, banana, Pandanus
Ae. (F.) togoi China (incl. Prov. of Taiwan), Japan, and Korean peninsula	Adults enter houses to feed on man.	Salt-water rock pools along the coast, artificial containers
Ae. (O.) vigilax Australian region, South-East Asia	Bites by day or night, indoors and outdoors. Vector of subperiodic W. bancrofti in New Caledonia. Observed flight: 96 km.	Brackish-water marshes and pools; fresh-water swamps and pools
Ae. (S.) polynesiensis Polynesia	Bites man by day in coconut groves, wooded areas, gardens, yards; and will also enter houses to feed. Flight limited.	Coconut half-shells discarded after removal of copra, rat-opened coconuts, tree holes, palm bracts, crab holes, barrels, tins, and other artificial containers
Ae. (S.) pseudoscutellaris Fiji Islands	Similar to those of Ae. polynesiensis	Similar to those of Ae. polynesiensis
Ae. (S.) tongae Tonga Islands	Bites outdoors by day in groves and plantations. Flight limited.	Coconut husks, tree holes, artificial containers
Anopheles campestris Thailand, Malaysia	Anthropophilic, endophilic.	Ricefields, marshes, ponds, ditches, pools
An. darlingi	(See Table 1.2.).	(See Table 1.2.)
An. funestus	"	"
An. gambiae	"	"
An. minimus flavirostris	"	"
An. punctulatus	"	"
An. donaldi Malaysia, Thailand	Bites man indoors at night and outdoors by day in the shade of the forest; also attracted to animals.	Ricefields, shaded swamps, drains, forest pools

Culex quinquefasciatus (fatigans) Worldwide in tropics and subtropics	Strongly domestic; bites man by night indoors and outdoors; rests by day in dark corners of bedrooms, sheds, culverts, etc. Observed flight: up to 11 km.	Especially polluted waters of drains, ponds, stagnant streams, pools; also tanks, barrels, tins, and other artificial containers
Mansonia annulata Malaysia, Indonesia, Philippines	Bites man by day or night, indoors and outdoors.	Swamp forests
Ma. annulifera South-East Asia	Enters houses at night to feed on man.	Open swamps, marshes, ponds; associated especially with Pistia
Ma. bonneae Philippines, Malaysia, Thailand	Bites man by day or night, indoors and outdoors; especially troublesome by day in the shade of the forest.	Swamp forests
Ma. dives Malaysia, South Pacific, Indonesia, India	Strongly anthropophilic; enters houses to bite man at night; attacks avidly by day in the shade of the forest.	Swamp forests
Ma. indiana Malaysia, Indonesia, India	Bites man indoors and outdoors, by night or day. Capable of long flights of several miles.	Open swamps, marshes, ponds
Ma. uniformis Worldwide in tropics	Bites man by day or night, indoors and outdoors. Capable of long flights of 32 km or more.	Swamps, pools, marshes; associated with Pistia, water hyacinth and swamp grasses

Important arboviral diseases transmitted by mosquitos

Disease and distribution	Epidemiology	Vector
Yellow fever tropics and subtropics, Central and South America, and Africa	In South and Central America, the disease is enzootic in jungle monkeys and transmitted by *Haemagogus* spp. In periurban and urban areas, *Ae. aegypti* acts as the principal vector and is responsible for epidemics in these situations. In Africa, monkey-to-monkey transmission in forest areas is maintained by *Ae. africanus*, with *Ae. simpsoni* breeding in the plantain and banana plantations at the periphery of the forest, and acting as vectors between monkey and man. Periurban and urban transmission by *Ae. aegypti* can reach epidemic proportions.	*Aedes aegypti* *Ae. africanus* *Ae. simpsoni* *Haemagogus spegazzini* *Ae. leucocelaenus* *Sabethes chloropterus*
Dengue tropico- and subtropicopolitan	Explosive urban epidemics; endemic survival in tropical cities; diffuse endemicity in rural areas of S.E. Asia and Oceania.	*Ae. aegypti* *Ae. albopictus* *Ae. scutellaris* *Ae. polynesiensis*
Chikungunya fever East and South Africa, and S.E. Asia	Africa: sylvan cycle in monkeys, baboons, and *Ae. africanus*; outbreaks with man-*aegypti*-man cycle in villages. S.E. Asia: urban outbreaks with man-*aegypti*-man cycle; possible supplemental transmission by *Ae. albopictus*; possible animal reservoirs.	*Ae. aegypti* *Ae. albopictus* *Ae. africanus* *Ae. taylori* *Ae. furcifer*
Western equine encephalitis North America	Basic cycle: bird-vector-bird-vector<(man) (equines) Reservoir in many species of wild birds; amplification of the virus in birds during the nesting season; transmission to man and equines in summer and autumn by *Cx tarsalis* in western USA; enzootic foci in swamps in eastern USA; transmission by *Cs. melanura*. Man and equines are incidental hosts.	*Culex tarsalis* *Culiseta melanura*

Eastern equine encephalitis Eastern USA, Caribbean, and Central and South America	Basic cycle: bird-vector-bird-vector<(man) (equines) Enzootic swamp foci with wild birds as reservoirs; transmitted by Cs. melanura; spillover to peri-domestic and domestic birds; sporadic transmission to man and equines in or near swamp foci by Cs. melanura; outbreaks in man and equines with Ae. sollicitans as the chief vector.	Cs. melanura Ae. sollicitans
St. Louis encephalitis USA, and Central and South America	Basic cycle: bird-vector-bird-(man). Rural epidemiology in western USA, with Cx. tarsalis as the chief vector; urban epidemiology in central and eastern USA, enzootic cycles in woods-inhabiting birds; transmission among peridomestic birds and domestic fowls and to man by domestic mosquitos.	Cx nigripalpus Cx pipiens Cx quinquefasciatus Say (= Cx p. fatigans Wiedemann) Cx coronator Cx tarsalis Psorophora ferox Sabethes chloropterus
Venezuelan encephalitis Southern USA, and Central and South America	Basic cycle: mammal-vector-mammal-vector-(man) Reservoir in forest rodents, epizootics among equines with equines as a source of virus for the vector; infection of man during equine epizootics.	Cx taeniopus Ae. serratus Ae. taeniorhynchus Ps. ferox Ps. confinnis Mansonia titillans
Japanese encephalitis Siberia to India	Basic cycle: pig-vector-pig-vector<(man) (horses); bird-vector (linked to vector and pig) Vertebrate hosts: heron, egrets, other birds; pigs, horses. Extensive outbreaks in man from time to time.	Cx tritaeniorhynchus Cx vishnui Cx gelidus Cx annulus
West Nile fever Africa to India	Basic cycle: bird-vector-bird-(man). Reservoir in birds; man incidentally infected.	Cx univittatus Cx antennatus
Wesselsbron fever Africa and Thailand	Basic cycle: transmission among sheep and other domestic animals by mosquitos; occasional transmission to man.	Aedes (B.) circumluteolus Ae. (O.) caballus
California encephalitis N. America	Basic cycle: vertebrate-vector-vertebrate; vector - vector; vector - (man). Reservoir hosts: hares, rabbits, ground squirrels, chipmunks; incidental infection in man. Generation-to-generation survival of virus in mosquitos.	Ae. canadensis Ae. trivittatus Ae. atlanticus
Murray Valley encephalitis Australia, New Guinea	Basic cycle: bird-vector-bird-(man). Reservoir in birds; man incidentally infected.	Cx annulirostris

Rift Valley fever South, Central and West Africa, and Egypt	Basic cycle: domestic animals-vector-domestic animals-(man). Extensive outbreaks in man from time to time.	Mansonia spp. Cx univittatus Cx pipiens Cx theileri

Table 1.6. Biology of important mosquito vectors of arboviral diseases

Species and distribution	Adult habits	Larval habitats
Aedes aegypti feral strain: Africa domestic strain: tropico- and subtropicopolitan	Rests and bites outdoors in African bush. Rests and bites indoors; intimate association with man. Flight limited.	Tree holes and other plant cavities Artificial containers — tins, tubs, etc. in and near houses
Ae. sollicitans Eastern USA and Greater Antilles	Vicious biter of man and animals by day or night. Capable of long flights, over 100 km.	Coastal salt marshes, inland salt pools
Ae. taeniorhynchus North, Central, and South America	Females attack man and animals by day or night; capable of long flights, over 35 km.	Coastal salt marshes
Ae. trivittatus N. America	Attacks man and animals by day in open woods and fields. Observed flight: 2.5 km.	Temporary rain and flood pools
Culex annulus Malaysia	Strongly attracted to pigs but will bite man.	Ricefields, ponds, brackish water pools, artificial containers
Cx antennatus Mediterranean and Ethiopian regions	Feeds on man and domestic animals.	Swamps, borrow pits, pools, ditches
Cx coronator North, Central, and South America	Feeds outdoors on avian and mammalian hosts.	Ground pools, seepages, hoofprints, tree holes, artificial containers
Cx gelidus Malaysia, China, Japan and India	Enters houses to feed on man; especially attracted to pigs.	Ricefields, marshes, ponds, pools, streams
Cx nigripalpus North, Central, and South America	Females feed on avian and mammalian hosts, including man.	Pools, ditches, marshes, swamps

Cx pipiens Holarctic region	Females feed on avian and mammalian hosts; a troublesome night-time biter, both indoors and outdoors. Flight ordinarily limited, but over 20 km observed.	Contaminated or fresh-water ground pools, ditches, cesspools, artificial containers
Cx quinquefasciatus (fatigans) Tropico- and subtropicopolitan	Similar to those of Cx pipiens	Similar to those of Cx pipiens
Cx taeniopus Central and South America	Presumably feeds in forests, primarily on rodents.	Forest rain and stream pools
Cx tarsalis N. America	In some situations, females prefer avian hosts, especially doves and pigeons; but in others, they feed primarily on animals especially cattle. They also bite man. Observed flight: 1.6-4 km.	Grassy, sunlit pools; irrigation ditches, seepages, marshes, hoofprints; clear or polluted water
Cx tritaeniorhynchus Oriental region and Africa	Bites man and animals by night, indoors and outdoors; especially attracted to pigs. Blooded adults rest in animal shelters by day.	Ricefields, marshes, ponds, pools, ditches, streams; cesspools
Cx univittatus Mediterranean and Ethiopian regions, Middle East and India	Ornithophilic but in some areas feeds readily on man and domestic animals.	Marshes, pools, grassy streams
Cx vishnui Oriental region	Bites man at night; also strongly attracted to cattle and pigs; also feeds on birds.	Ricefields, pools, ditches, swamps, rain pools
Culiseta melanura Eastern and Central USA	Females feed by preference on swamp-inhabiting birds but also attack domestic and wild animals, reptiles, and occasionally man.	Swamps, bogs
Haemagogus spp. Central and South America	Feeds on monkeys and other animals by day in forest canopy; occasional feeding on man at ground level, especially after trees are fallen. Flight limited.	Tree holes and other plant cavities in the forest
Mansonia titillans North, Central and South America	Fierce biter of man and animals from dusk to dawn. Capable of long flights of several miles.	Ponds, lakes, impoundments with Pistia and other suitable plants, to which larvae and pupae can be attached by their air tubes

Psorophora confinnis North, Central and South America	Fierce day and night-time biters of man and animals in vicinity of the breeding habitats. Observed flight: 8-13 km.	Temporary rain and flood pools
Ps. ferox North, Central and South America	Fierce day and night-time biter in woods near breeding places. Observed flight: 2 km.	Temporary rain and flood pools
Sabethes chloropterus Central and South America	A long-lived species with a preference for the forest canopy but also bites man at ground level.	Rot holes in trees